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ELEMENTS

OF

CHEMISTRY:

INCLUDING

A COPIOUS SELECTION OF EXPERIMENTS,

AND

MINUTE DIRECTIONS FOR PERFORMING THEM.

TOGETHER WITH

NUMEROUS APPLICATIONS TO THE ARTS AND PURPOSES OF LIFE.

ADAPTED TO

THE USE OF SCHOOLS AND ACADEMIES.

BY ALEXANDER FISHER OLMSTED, A. M.

NEW HAVEN:
PUBLISHED BY S. BABCOCK.
1851.

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PREFACE.

Although the following work is a compilation, and can hardly aspire to the praise of great originality, yet the author ventures to hope that it will be found, on examination, to bear a favorable comparison with similar works, in perspicuity of style and arrangement, in practical utility, and in adaptation to the wants of young learners,—a class for whom it is especially designed.

The author has studied simplicity in the arrangement, by distributing the whole subject into three general heads, denominated respectively, *General Principles and Laws*, *The Elements and their Combinations*, and *Organic Chemistry.* Since most of the pupils in our schools have the opportunity of studying appropriate works on Natural Philosophy, he has not deemed it necessary or advisable to treat here of the *mechanical* laws of attraction, heat, light, electricity, and magnetism, but by confining himself strictly to *chemical* laws and phenomena, he has gained space to treat those subjects with the greater freedom and fulness, and to dwell more at large on their important applications to the arts and to the phenomena of nature.

With the hope of rendering the work more useful to the pupil, and more acceptable to the instructor, three articles are added: one on *Experiments*, containing a copious selection adapted to a complete illustration of the text; the second on *Chemical Processes*, describing various operations of the laboratory; and a third on *Chemical Apparatus*, in which certain forms of apparatus not mentioned in the former parts of the work are described.

In the preparation of the work, a great number of the most approved authorities have been consulted, but more especial use has been made of the excellent treatises of Fowne & Gmelin. The author has also been favored with the advice of his father, Professor Olmsted, and has received many valuable suggestions from Mr. William J. Craw, of the Yale Analytical Laboratory.

New Haven, June, 1851.

ADVERTISEMENT

All the engravings of this work are published in a pamphlet form, which may be had at a trifling expense. The publishers have printed the figures in this separate form at the request of several teachers, that the pupils might be able to recite from the figures without the text. A few of these pamphlets may answer the purpose of a set of expensive diagrams.

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ELEMENTS OF CHEMISTRY.

PART I.

GENERAL PRINCIPLES AND LAWS.

DEFINITIONS AND GENERAL PROPERTIES OF MATTER.

1. **Chemistry** is that science which has for its object, to investigate the composition of bodies, and the changes of constitution which they produce by their action on each other.

Natural philosophy respects *masses;* chemistry, *particles* of matter.

Air, earth, and water, when considered with reference to their constituent elements, belong to chemistry; when in relation to the vast masses of the atmosphere, the land, and the ocean, they come under natural philosophy.

2. Chemistry is divided into *organic* and *inorganic*, corresponding to the two great departments of nature,—the living and the inanimate. Organic chemistry investigates the composition of *bodies possessing life, and the changes produced in these bodies by other substances.* Inorganic chemistry pertains to inanimate nature, and includes the composition and mutual agencies of bodies not organic.

3. The properties of matter are *chemical* or *mechanical.* The chemical properties are *those which produce a change in the constitution or nature of bodies;* the mechanical, *those which alter their figure or position.* The extraction of the juice of apples by pressure, is mechanical; but the spontaneous change which the juice undergoes by fermen-

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1. How is Chemistry defined? How are Natural Philosophy and Chemistry distinguished?

2. Into what parts is Chemistry divided? What is the object of organic Chemistry? What is the province of inorganic Chemistry?

3. How are the mechanical and chemical properties of matter distinguished? In making cider, what part of the process is mechanical? What is chemical? What part of the process of making bread is mechanical? What is chemical?

tation, is chemical. The mixing of flour, yeast, and water, is a mechanical operation; but these ingredients pass through a chemical process when they ferment and are converted into bread.

4. *Analysis* and *synthesis* are two methods of inquiry into the constitution of bodies. Analysis is derived from a Greek word, which signifies "to resolve," and denotes the resolution of a body into its component parts. It is *that method in chemistry by which the elements of a body are discovered by resolving it into its component parts.* Synthesis is the opposite of analysis. It is derived from a Greek word, signifying "to put together." It is *that method in chemistry by which the constitution of a body is determined by uniting its components.*

5. In entering upon the study of chemistry, it is necessary to understand the following properties of matter:

(1.) All matter is made up of a vast number of extremely minute particles, called *molecules*, or *atoms*. The particles of one grain of copperas (sulphate of iron) dissolved and diffused in twenty-four million grains of water, will still be easily detected by the proper chemical test.*

(2.) *Matter is indestructible.* The elements of which bodies are composed, are continually changing their forms and modes of combination; but in all these changes of form, they still remain unchanged in their nature and properties. Fire consumes wood, and the wood appears to be destroyed; but from its combustion other plants derive new life, imbibing through their leaves, or the soil, most of that which escapes in smoke or remains behind in ashes. Ice is changed into water, and water into steam, by heat; but in the form of clouds and rain, of dew, snow, and hail, watery vapor is returned again to the earth. Ceaseless change, with a final restoration of every particle of matter, attends all the phenomena of nature.

(3.) *Attraction* is a tendency of different portions of matter towards each other. It may exist between masses or particles. The attraction between masses is called *gravitation*, and the consideration of it belongs to natural philosophy;

* Ferrocyanuret of potash.

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4. What is analysis? What is synthesis?

5. Of what is all matter made up? Is any portion of matter destroyed or lost? Does fire destroy, or only change the form of matter? What becomes of smoke and ashes? Is water lost when converted into vapor? How does it return again to the earth? What is attraction? How is gravitation distinguished from aggregation, affinity, and cohesion? What is said of aggregation?

that between particles belongs to chemistry, and includes *aggregation*, *affinity*, and *cohesion*. Aggregation unites particles of the *same* kind in one body, as the particles of lead in a musket ball. Affinity unites *different* particles in one body, as particles of copper and zinc to form brass. Cohesion unites particles *mechanically*, and may be overcome by mechanical means, as that of a lump of sugar by grinding. The attraction of gravitation acts at *all distances*, as when a ball falls towards the earth, or when the sun attracts one of the planets. The several kinds of attraction which exist between the particles of matter, act only at *insensible distances*, as the force which binds together particles of gold by aggregation, or particles of copper and tin in bell metal by affinity, or grains of sandstone by cohesion.

(4.) *Repulsion* is opposed to attraction in all its forms. Attraction binds together the particles of matter; repulsion causes them to separate more widely. In solids, attraction prevails; in liquids, attraction and repulsion are in equilibrium; and in gases, (or bodies in the form of air,) repulsion entirely overcomes the force of attraction. These effects generally depend upon heat. At a low temperature attraction prevails; *almost all bodies assume the solid state at a low temperature.* At a higher degree of heat, repulsion neutralizes and finally destroys cohesion, and all bodies assume the gaseous state. Thus, zinc at common temperatures is solid, the particles being firmly united by cohesion; at a higher temperature it melts, and at a very high temperature it is volatilized, or driven off in vapor or gas.

OF HEAT.

6. The cause of the phenomena of heat is unknown, but it is supposed to be a highly attenuated, imponderable sub-

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What force unites copper and zinc to form brass? What is said of cohesion? By what force does a body fall to the earth, or a planet revolve around the sun? At what distance does gravitation act? How are the attractions of aggregation, affinity, and cohesion defined? To what is the force of repulsion opposed? What is the action of these two forces on the particles of matter? Does repulsion or attraction prevail in solids? In liquids, what is the state of these two forces? Which prevails in gases? On what do these forces generally depend? Does attraction prevail at a high or low temperature? At which temperature does repulsion prevail? How is the solid state of zinc explained? Why is zinc melted? Why is it driven off in vapor at a high temperature?

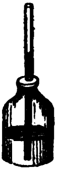
stance, the particles of which repel each other, but are attracted by other substances. To this substance the name *caloric* is given. It will be convenient to consider the phenomena of heat under the following heads; 1. *Its effects:* 2. *Its distribution:* 3. *Its quantity:* 4. *Its sources.*

7. The leading effects of heat are, to enlarge the dimensions of bodies, and to reduce solids to liquids and liquids to gases. These effects are designated by the terms *expansion, liquefaction, evaporation and vaporization.* The withdrawal of heat reduces gases to liquids and liquids to solids; the first is called *condensation,* and the second *congelation.*

EXPANSION.

8. *All bodies, whether solid, liquid, or aeriform, are expanded by heat and contracted by cold.* In solids, the degree of expansion is usually small, and differs much in different bodies, but is greatest in the metals. Liquids expand by heat much more than solids. They differ, however, from each other in the power of expansion, and even the same liquid is not expanded equally at different degrees of temperature, being more expanded at a high than at a low temperature by equal additions of heat. Thus 10° added to alcohol when hot, will expand it much more than the same number of degrees applied to it when cold. Those liquids vary most at different temperatures, whose boiling points are the lowest. Gases expand much more than either solids or liquids. The great expansion of air by heat may be shown by filling a small phial (Fig. 1.) about half full of water, colored with cochineal or carmine. Through the cork a tube passes nearly to the bottom of the phial. If the hand be applied to the top of the phial, the air within will be expanded and drive the liquid up the tube and out of the top. It will be necessary to cement the cork so as to be air tight. The expansion of substances by heat is a principle of great value and of frequent application. In putting tire upon wheels, blacksmiths make the iron rim

Fig. 1.



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6. What is supposed to be the cause of heat? What name is given to this substance? Under what four heads are the phenomena of heat arranged?

7. What are the leading effects of heat?

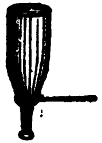
8. State the principle of expansion by heat. Are solids, liquids, or gases expanded most by heat? Among solids, what bodies expand the most? Are different liquids expanded equally? Will the same amount of heat added to a liquid always raise its temperature in the same degree? What is said of alcohol? Which liquids vary most at different temperatures? Explain Fig. 1.

a little smaller than the wheel, and then heat it red hot. This enlarges the rim to such a degree that it will readily encompass the wheel. When this has been applied to the wheel, it is suddenly cooled, and by its contraction binds the work very firmly together.

A piano gives a higher tone in a cold than in a warm room, on account of the contraction of the strings; a nail driven into the wall, becomes loose after a time, because the iron expands in summer and contracts in winter more than stone or wood, and thus the opening is gradually enlarged. For this reason, in the construction of railroads, the rails must not be laid too closely together; in the arrangement of steam pipes, they must not be too firmly inclosed. In roofing, the zinc plates, instead of being nailed together, must overlap each other, that they may neither tear nor warp by alternate contraction and expansion. Gas pipes are laid several feet beneath the surface of the ground, that their joints may not be loosened by changes of temperature.

9. A very useful application of expansion by heat, is in cutting glass by a hot iron, as is constantly practised in the laboratory. The glass to be cut is marked with ink in the desired direction, and then a crack, commenced by any convenient method, at some distance from the desired line of fracture, may be led by the point of a heated rod along this line with the greatest precision. If the neck of a bottle be turned around in a red hot iron rod, and then suddenly dipped in water up to the heated line, it will be instantly taken off as smooth and true as if it were cut by a diamond. White glass bottles answer better for this experiment than the thicker dark colored. Hard rocks are sometimes broken in the same manner. A fire is kindled on the rock sufficient to render it nearly or quite red hot. Cold water is then suddenly dashed on, and the rock splits into numerous fragments, which are easily removed by wedges.

Fig. 2.



10. In warm weather the rod of the pendulum is lengthened, and the clock goes too slow; in cold weather it is shortened, and the clock goes too fast. To remedy this irregularity in

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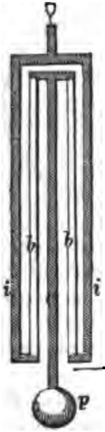
How is the principle of expansion by heat applied in putting tire on wheels? Why does a piano give a higher tone in a cold than in a warm room? Why does a nail gradually become loosened from a wall into which it is driven? What is the method of laying rails on a railroad? What other examples are given?

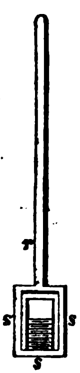
9. Explain Fig. 2. How are hard rocks sometimes broken?

Fig. 3.



the movement of a clock, a pendulum has been contrived, which is called, from its form, the *gridiron pendulum*. (Fig. 3.) The shaded bars, *i*, *i*, *e*, are made of iron: the light bars, *b*, *b*, of brass. During the heat of summer the bars *i*, *i*, will expand a certain length, as to the line, *a;* but the same time the bars, *b*, *b*, will expand upwards more than *i*, *i*, expand downwards, because brass expands more than iron. The pendulum, *p*, would therefore be elevated instead of lowered by these two expansions. But the bar, *e*, also expands downwards, and therefore lowers the pendulum, *p*, to the proper distance from its point of suspension. By adjusting the length of the bars, *i*, *i*, *e*, and *b*, *b*, to each other, it is evident that the compensation pendulum will keep nearly the same time at all temperatures.

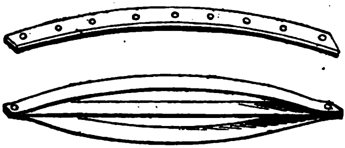
Fig. 4.



A still simpler compensation pendulum is thus constructed. The weight, *p*, instead of a metallic disk, consists of a cylindrical glass jar, (Fig. 4,) containing mercury. This glass jar is held in the extremity of the steel pendulum rod, *s*, *s*, *s*, called the "stirrup." The same increase of temperature which will cause the rod, *r*, to descend, and become longer, will also cause the mercury to rise, so that *the center of motion of the pendulum shall be at the same distance from the point of suspension.*

When different metals are united together, as a strip of iron to a strip of brass, (Fig. 5,) and exposed to heat, their different degrees of expansion will cause the compound bar to assume a curved figure. If three strips of metal, as copper, zinc, and tin, be riveted only at their extremities, the tin being between the other two metals, they will be bent into a curve on each side of the strip of tin.

Fig. 5.



11. A similar arrangement is applied in the construction of the balance wheel of a watch, (Fig. 6.) Every

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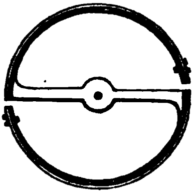
10. What evil is the gridiron pendulum designed to remedy? Explain its construction from Fig. 3. How is the mercurial pendulum constructed?
11. Explain Fig. 5. How is the balance wheel of a watch constructed?

Fig. 6.



increase of temperature must increase the diameter of the wheel, and consequently greatly affect its rate of going. To obviate this, the circumference of the balance wheel is made of two metals, the most expansible being on the outside. The compound rim is also cut through in two or more places, as represented in the figure. The effect of this arrangement is, that when the temperature of the wheel is increased, the rim bends inwards, as in the first part of Fig. 5, *towards the center*, thus compensating the expansion of the diameter which would carry it *from the center*. The center of gravity of the rim, therefore, remains at the same distance from the center of the wheel, which is essential to its uniform motion.

12. Wherever iron is used, in the building of grates for fires, in constructing iron bridges, &c., it is indispensable to make provision for the changes of dimensions by expansion and contraction. The two side walls of the Gallery of Arts and Measures, at Paris, having become inclined outwards by the great weight above, the walls were perforated on opposite sides, and strong iron bars introduced. The ends of these bars projected beyond the walls, and were furnished with strong circular iron plates, fitted on so as to screw up firmly to the sides of the building. The bars were then heated, and expanded to such a degree by the heat, that the iron plates were separated from the walls. These were then screwed up to the walls. On cooling, the bars contracted and drew the walls closer together. This process being repeated, the walls were brought to a perpendicular position.

13. By the expansion of heat, the *thermometer* indicates changes of temperature. This instrument consists of a glass tube (Fig. 7,) with a hollow ball, *a*, called the bulb, and a graduated scale, *d*. The bulb and part of the tube are filled with quicksilver, which by its expansions and contractions indicates the changes of temperature. To measure them, the scale, *d*, is divided into equal parts, called degrees, and applied to the tube. The thermometer commonly used in this country is called Fahrenheit's, from the fact

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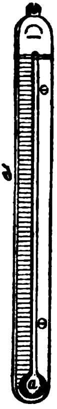
12. In what works of art is it necessary to guard against the effects of expansion? What is said of the Gallery of Arts and Measures, at Paris?

13. What is the object of a thermometer? Describe this instrument. By whom was the common thermometer first constructed? What process did

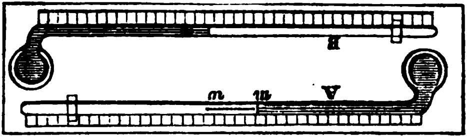
Fig. 7.



that it was first constructed by Fahrenheit, a citizen of Amsterdam. Fahrenheit thought that by mixing snow and salt he had obtained the point of absolute cold. He therefore called this point zero, or 0. He then plunged his thermometer into freezing water, and marked the place on the thermometer tube where the mercury stood. Having marked this point, he now plunged his thermometer into boiling water, and marked the height of the mercury. From these three points, the temperature of the mixture of snow and salt, that of freezing water, and that of boiling water, he determined all the divisions of the scale. From boiling to freezing water, he made 180 small divisions, or degrees, and continuing the same scale below the freezing point, he made 32 degrees to zero. From zero, therefore, there are 32° to the freezing point, and from the melting point of ice to the boiling point of water, there are 180° more, or 212° in all, from zero to the boiling point.

14. *The self-registering thermometer* (Fig. 8.) is formed by two thermometers of different construction. A is a thermometer partly filled with mercury. At the top of the mercury, *m*, is a small piece of steel wire, *w*. When the mercury in the thermometer expands, it pushes the wire before it. When it again contracts, it leaves the wire on the side of the tube, and thus the position of the wire in the thermometer, as at *w*, shows the *greatest height* to which the mercury has risen. This instrument is used to determine the extreme heat during the night, or other times during the absence of the observer.

Fig. 8.



To ascertain the *greatest cold*, another thermometer, B, is placed on the same stand. This thermometer is partly filled with spirits of wine. It contains a cylinder of porce-

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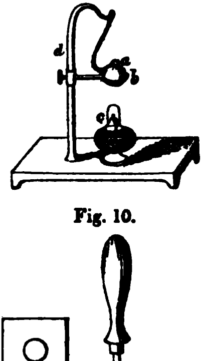
Fahrenheit pursue? At what point did his thermometer commence? How many degrees are reckoned from zero to the freezing point of water? How many to the boiling point?

14. What is the instrument represented in Fig. 8 called? What is its construction?

lain, which adheres to the spirits of wine as it contracts, and is thus drawn back to the lowest point of cold. When the fluid expands again, it passes readily through the cylinder of porcelain, leaving it on the side of the tube at the lowest point of contraction. The porcelain is restored to its position for a new observation, by inverting the thermometer, and the iron cylinder is drawn into its place by a magnet.

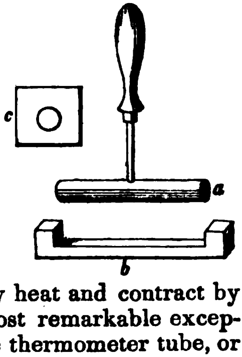
15. To determine temperatures above a red heat, an instrument, called Daniel's *pyrometer*, is employed. In this instrument a bar of iron, or platinum, is so arranged, that its expansions or contractions are registered, and thus very high temperatures may be determined. It has been shown that brass melts at 1869°, copper at 1996°, gold at 2000°, and cast iron at 2786°.

Fig. 9.



16. A metallic ball, *a*, (Fig. 8.) provided with a ring, *b*, a little larger than itself, will, when heated by a lamp, be supported by the ring, but when the lamp is withdrawn, gradually cooling, it will contract until it falls through the ring.

Fig. 10.



In Fig. 10, a bar of metal, *a*, is provided with a handle, and fits into a guage, *b*, and also passes through the hole in *c*. When the bar is heated, it expands lengthwise, and therefore will not enter the guage, *b*, as at first; it also expands in diameter, and therefore it will no longer pass through *c*. If, on the other hand, it is cooled with ice or snow, it will not fill the guage, and it will pass loosely through *c*.

17. The law that bodies expand by heat and contract by cold, is not universally true. The most remarkable exception is in the case of water. A large thermometer tube, or bulbed glass, filled with water and placed in a cold situation, will show a contraction in the column of water, until it has reached a cold of 39°, when the contrary effect will take

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15. What instrument is used to determine very high temperatures? How are high temperatures indicated by this instrument? At what temperature does brass melt?—copper?—gold?—cast iron?

16. Explain Fig. 9. (The explanation of every figure should consist of two parts; first, the *design*; secondly, the *description*. No explanation can be perfect where either of these is omitted.) What is the object and description of Fig. 10?

place. From 39° to 32° the water will expand, and at 32°, in freezing, a sudden expansion will take place, so great as often to break the bulb of the glass tube in which the water is contained.

The exception in the case of water to the general law of expansion and contraction, was dictated by a benevolence which is ever working out the highest welfare and happiness of creation. All laws appear to be subordinate to a main design—the *greatest good*. So far as these laws carry out this design, they prevail; and when in particular circumstances they fail in this respect, they give way to *exceptions*, or laws of a more limited character. These principles are beautifully illustrated in the case of water. In the present arrangement, on account of the expansion of water in freezing, ice is lighter than water, and therefore floats on its surface. But were water to contract in freezing, ice would be heavier than water and would sink. In this case, the coating which now protects our rivers and streams from the extreme cold of winter, would be itself covered, and effectually guarded on the return of Spring against its warmth and that of the ensuing summer. In the next winter this deposit of ice would be increased, and this process, in successive winters, would eventually fill our rivers and streams with ice, destroying all the animals with which they are now filled, and blocking up navigation.*

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* It is commonly stated that the water of the ocean, &c., would be suddenly converted into ice after being reduced to the freezing point. We do not, however, think this possible, as the immense amount of heat given out in congelation, especially where the escape of this heat was more or less retarded, as beneath the surface of water, would render the conversion of the whole mass into ice a gradual process, and we do not see how it could take place except by a continual transfer of ice from the surface to the water beneath. On the other hand, the vast amount of heat given out by congelation could not so augment the general temperature as to prevent the freezing of the entire waters of the globe, though it would retard this effect. No cause whatever of heat, but a constant, unfailing source, like the sun, can produce any permanent change in the temperature of the earth; for whatever heat would be added from any other source, as by the congelation of immense masses of water, would be soon radiated into the cold regions of space surrounding the earth, and a new supply would be in like manner radiated and lost, until sooner or later all the heat from this source would be exhausted. No warmer summer would succeed to this immense loss of heat of congelation during the winter, and the second winter would cause an equal and permanent loss of this heat, until, in successive winters, the effect would be accomplished of freezing the entire waters of the globe.

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17. What remarkable exception is there to the law that bodies expand by heat and contract by cold? By what experiment may this be illustrated? What appears to be the main design of creation? Are not general laws essential to this design? Are these laws without exceptions? Are the exceptions equally evincive of benevolence? Why is water near the freezing point an excep-

There are many liquids besides water, which expand before assuming the solid form. Several melted metals exhibit the same phenomenon, and advantage is taken of this fact in the arts. The alloy of which printers' types or stereotype plates are formed, expands as it solidifies, and hence forces itself into every part of the mould, and copies it perfectly; the same is the case with melted iron. From such a metal as lead, which contracts as it cools, it would be impossible to obtain good castings.

18. *The expansion of vapors and gases is the same for an equal degree of heat.* Not only the amount, but the *rate* of expansion, is uniform for all degrees of heat. This rate or amount is equal to $\frac{1}{460}$ of the volume of the gas at zero, for each degree of the thermometer. The expansion of air by heat is one cause of winds and atmospheric currents. Balloons are sometimes made to ascend by the expansion of air within them, and their consequently increased levity. A balloon made of tissue paper, or silk, (Fig. 11.) is filled with heated air, which rises through an aperture in the lower part. The heat is produced by the flame of a sponge soaked in alcohol, which is suspended from beneath, and the air within the balloon becoming in this way rarefied, causes the whole to ascend, on the same principle that a cork rises in water.

Fig. 11.

CHANGES OF STATE.—LIQUEFACTION AND CONGELATION.

19. Solids are converted to liquids, and liquids to vapors, or gases, by the addition of heat; the opposite phenomena of condensation and congelation take place with the withdrawal of heat. Fusibility, or liquefaction, is a property of all solid bodies, although some are much more fusible than others. Lead and wax are easily melted, but lime and rock-crystal cannot be melted by the highest furnace heat. These substances may, however, be fused by the intense heat of galvanism, or by the oxy-hydrogen blowpipe.

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tion to the general law that bodies contract by cold? Are there any other liquids besides water that expand on assuming the solid form? What solids exhibit the same phenomenon? What use is made of this property of certain metals in the arts? Why is it not possible to obtain good castings from lead?

18. What is the law of expansion in gases and vapors? What effects are produced by the expansion of air by heat? Why do balloons, containing heated air, rise? Explain Fig. 11.

19. What is said of the fusibility of bodies?

20. The following are some of the most important facts connected with the liquefaction of bodies:

(1.) ***While a solid is melting, its temperature does not increase.*** Thus, if ice be placed over a fire, it will rise to a temperature of 32°, and will remain there until every part of it is melted. The same is true of every solid. All heat added to a body in this state, appears to be lost, as it does not raise its temperature. This, therefore, is called ***latent heat***, or ***that portion of heat which disappears in bodies while they are changing their state from solids to liquids, or from liquids to vapors or gases.***

The quantity of heat which disappears in ice in changing its form to water, is 140°. This may be proved in the following manner: Take two tumblers, one containing a pound of ice at 32°, or the freezing point, and the other a pound of water at 172°. Pour the water from the second tumbler into the first. If no heat disappeared, the mixture would be at 102°, or midway between 172° and 32°. But in fact, the water poured in from the second tumbler has lost all its heat, and the mingled water of both tumblers has the temperature of that of the first, or the mixture stands at 32°. And still a change has been produced in the first tumbler, though not in temperature, yet in *form*, for its ice has become water. The change of the water of the second tumbler is in *temperature*, being cooled down from 172° to 32°, having lost 140° of heat. This may be illustrated in numbers in the following way:

$$\left.\begin{array}{l}\text{1 lb. of } \textit{water}(1) \text{ at } 32^\circ\\ \text{1 lb. of water}(2) \text{ at } 172^\circ\end{array}\right\} = \text{2 lbs. water at } 102^\circ.(5)$$

$$\left.\begin{array}{l}\text{1 lb. of } \textit{ice}(3) \text{ at } 32^\circ\\ \text{1 lb. of water}(4) \text{ at } 172^\circ(6)\end{array}\right\} = \text{2 lbs. water}(8) \text{ at } 32^\circ.(7)$$

The first formula is a mixture of *water*(1) with water.(2.) The second, of *ice*(3) with water.(4.) In the first case, a *mean*(5) is obtained; in the second, all the heat of the second tumbler(6) above 32°,(7) or 140°, is lost, while the ice(3) is converted into water.(8.)

21. Again, let there be a uniform cause of heat, as a brightly burning fire, which shall raise the temperature of a pound of water placed over it, 10° per minute. Starting with *water* at 32° in 14 minutes, this will have a tempera-

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20. What is the first important fact connected with the liquefaction of bodies? How is latent heat defined? How much heat disappears in ice in changing it to water? What is the first method by which this is proved?—the second?

ture of 172°; but with the same quantity of *ice* in the same time, the temperature will still be 32°, and no apparent effect will be produced by the fire besides melting the ice. From these experiments it is evident, that 140° of heat disappear in changing ice to the liquid state. This is therefore the amount of latent heat in water.

22. The latent heat absorbed while bodies are converted from the solid to the liquid state, renders *liquefaction a cooling process.* When ice melts in contact with other bodies, it withdraws heat from those bodies. Thus, when placed in a tumbler of water, it reduces the temperature of the water, and this abstracts heat from the tumbler, and the whole becomes cold. A small piece of ice will thus cool a large portion of water, though it floats one tenth out of the water, and is exposed to a draught of air on a warm summer's day, the tumbler itself being also surrounded by this warm air. When snow melts in the hand a painful sensation of cold is produced, and when on the feet it often causes violent colds and other diseases.

The amount of latent heat varies greatly with different substances as appears from the following table:

Water,	142°.	Zinc,	49°.
Sulphur,	17°.	Tin,	26°.
Lead,	9°.	Bismuth,	22°.

23. The design of this principle of latent heat is obvious. It is a most effectual rampart against disastrous floods, which would arise from the too sudden melting of snow in spring. It retards the advance of winter, and delays the approach of summer, rendering the progress of one season to another more gradual. It tends to give greater uniformity to climate, and to prevent the alternation of warm days and sudden frosts, by which fruits are cut off and vegetation injured.

24. When liquefaction can be by any means hastened, the intensity of the cold is increased, the whole amount being produced in a shorter time. In *freezing mixtures* (1),* this is accomplished by a weak chemical attraction, existing between the materials of the mixture. Thus, the affinity of salt for water, causes it to hasten the liquefaction of snow, and to produce great cold.

*These numbers refer to experiments and illustrations at the end of the book.

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22. What is the design of the principle of latent heat?
23. Why is liquefaction a cooling process? How is this illustrated? What is said of the latent heat of different substances?
24. What produces the intense cold of freezing mixtures?

25. On the other hand, the *congelation* and the *diminution of volume* of any body, will cause a portion of its latent heat to become sensible. Numerous blows will condense iron, and great heat will be evolved. Water becomes solid in the process of slaking lime, and the heat given out is so great as to set fire to light and combustible bodies. Ships freighted with lime, are in this way sometimes set on fire. Sulphuric acid and water, when mingled, are condensed into a smaller volume, and great heat is produced.

Congelation produces heat by giving out the heat which is essential to the liquid form, when that liquid is converted into a solid. The freezing of water produces heat, because the heat which was latent in the water, becomes sensible when the water returns to the frozen state.

VAPORIZATION AND EVAPORATION.

26. The conversion of fluids into vapors, when performed artificially, is called *vaporization;* when it occurs naturally, *evaporation.* When vaporization is carried on rapidly, a violent agitation of the fluid takes place, to which the term *ebullition* is applied. Ebullition is caused by the formation of vapor, on the side next to the heat which rises through the fluid, and is succeeded by another portion formed in the same way, and thus the process is continued until the heat is removed, or the liquid is entirely converted into vapor. Water, when converted into vapor, expands 1696 times, alcohol 660 times, and ether 443 times.

27. *The boiling point is that temperature at which a liquid undergoes ebullition.* Thus mercury boils at 662°; oil of turpentine at 316°; water at 212°; alcohol at 173°; and ether at 96°. Two circumstances attend the ebullition of fluids which are to be particularly remarked—

(1.) *Fluids boil at different temperatures under different degrees of pressure.*

(2.) *Under a given pressure, the temperature of boiling always remains the same.*

The surface of all fluids is exposed to the pressure of the

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25. What is the effect of the congelation of a body upon its latent heat? Does the diminution of volume produce the same effect? Why does iron give out heat when hammered? Why is heat given out in the process of slaking lime?

26. How is vaporization defined? Evaporation? What is meant by the term ebullition? What is the cause of ebullition? How much does water expand when converted into vapor? Alcohol? Ether?

27. What is meant by the boiling point of a liquid? What examples are given? What two circumstances are mentioned as attending the ebullition of fluids?

atmosphere; if this be removed, they will boil at a temperature lower than common. It is found that the boiling point is reduced 140°, by removing atmospheric pressure. The same effect, to a greater or less extent, is produced at great elevations above the surface of the earth. The pressure of the atmosphere becomes less and less, as we ascend, until at the height of Mont Blanc, or fifteen thousand feet, water boils at 187°, or 25° lower than it does at the level of the sea. In most inland countries, the boiling point is somewhat less than 212°, on account of the elevation above the general level. Were the pressure of the atmosphere entirely removed, water would boil at 72°. As in the central regions of the earth, the thermometer is usually above this temperature, were the pressure of the atmosphere entirely removed, the whole of the waters of these regions would boil with violence, until a new atmosphere of vapor was supplied. After such an atmosphere had been formed, the boiling of the water would cease, and evaporation and condensation would go on as they do now, but much more suddenly, and on a vast scale.

28. The principle that liquids boil at a lower temperature under diminished pressure, is applied in the arts to the boiling of sugar. A large boiler, or *vacuum pan*, is connected, by a bent iron tube, inserted in the top, with an *air pump*, which removes the vapor from the boiling sirup. In the lower part of this tube, joining the air pump and the vacuum pan, is a *cistern pipe*, to receive any of the sirup which may boil over. A *measure cistern*, stands on a higher level than the boiler, or vacuum pan, which holds about twenty gallons, which quantity of sirup is admitted at a time. A metallic case surrounds the lower part of the vacuum pan, which is filled with steam at a pressure lower than that of the atmosphere, and consequently at a temperature less than 212°. The ordinary pressure of this steam is only about four or five pounds to the square inch, and its temperature 155°, which is found sufficient to cause the sirup within the vacuum pan to boil rapidly. Steam is also

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What is the effect of removing the atmospheric pressure from the surface of fluids? Why does water boil at a lower temperature on the summit of Mont Blanc than at the level of the sea? At what temperature would water boil, were the pressure of the atmosphere entirely removed? What would be the effect of the removal of this pressure upon the waters of the globe?

28. To what purpose, in the arts, is this principle applied? Describe the process.

introduced *within* the vacuum pan, by several coils of pipe, which arrangement greatly increases the rapidity of the evaporation. In these pipes the steam is usually of a higher pressure and temperature, than that introduced into the case, at the bottom of the vacuum pan. The air pump is kept in constant action, by a steam engine. When the pressure within the boiler is about $\frac{1}{30}$ that of the atmosphere, the sirup boils at only 115°; when it is about $\frac{1}{7}$ that of the atmosphere, it boils at 175°. The reason for boiling sirup at this low temperature, as well as the remainder of the process of making sugar, will be explained hereafter.

29. By increasing the pressure on the liquid, the boiling point may be raised indefinitely; and this increased temperature has been found greatly to augment the *solvent powers* of water. For this reason, a strong metallic vessel, called Papin's Digester, in which water may be heated under a powerful pressure, has been sometimes employed in dissolving hard animal substances, which cannot be dissolved by boiling in the ordinary way. Soups are sometimes prepared in this manner, and in the laboratory, substances are dissolved otherwise not easy of solution. The *expansive force* of water is greatly augmented when thus heated in a confined state. At a temperature of 400°, this force equals 16 times the pressure of the atmosphere, or about 240 pounds to the square inch.

30. *Under a given pressure, the temperature of liquids, while boiling, remains the same.* This is true whether they are boiled with a high, or a moderate heat. The effect of an intense fire, is only to increase the *rapidity* of the ebullition. This is owing to the fact, that water in being converted into *steam*, renders latent a great amount of sensible heat. When water at 32° is mixed with an equal weight of *water* at 212°, the whole is found to possess a mean between the two temperatures, or 122°; but when equal weights of water and steam are mixed, or an equal weight of steam is condensed in water at 32°, it raises 5·6 parts of the latter up to the boiling point, or through a range of 180°. Multiply, therefore, these 180°

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29. What is the effect of increasing the pressure on fluids? For what purpose is Papin's Digester sometimes employed? What is said of the expansive force of water when thus heated under pressure?

30. What effect is produced by an intense fire on the ebullition of fluids? What is the latent heat of steam? How is this proved?

by the 5·6 parts of water, ($180^\circ \times 5{\cdot}6 = 1008^\circ$,) and it equals 1008°. Therefore, the steam has added to the temperature of the water in which it was condensed 1008°, or has lost this amount of heat at the same time with its aeriform state, or its change into water. Therefore, 1008° may be considered as the latent heat of steam.

31. Another method gives nearly the same results. Five gallons of water are heated in Papin's Digester, to 400°. A vent is suddenly given to the steam, and one gallon allowed to escape in the form of steam. This sudden conversion of one gallon into steam, reduces the temperature of the remaining four gallons to 212°. Five gallons, therefore, (including the steam which escaped at 212°,) have been reduced to 212°, and have, consequently, lost (400—212=) 188°. Multiply this number by 5, and 940° is the amount of sensible heat lost, or that which has become latent in the steam. The former method gave 1008°, which is probably nearer the truth, as the latter method is not as susceptible of great accuracy.

32. The vast amount of heat which steam absorbs, is given out again when it is condensed. Hence the value of steam as a source of heat, for which it is used, in warming apartments, in drying gunpowder, and other purposes, where a mild uniform temperature is required. In the laboratory, steam baths, of various forms, are used for the purpose of drying filters and other objects where excessive heat would be hurtful.

Fig. 12.

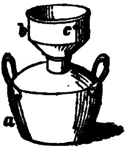

Fig. 12, represents a very simple and convenient form of the steam bath. The lower part, *a*, is a common steam boiler. The upper part, *b*, is made double; between the inner and outer portions, a space being left for the steam to pass, which issues near the top, at the small hole, *c*. The space within this upper part, is therefore kept by the steam continually at the boiling point, or 212°, and filters or other objects placed within this, are soon dried at this temperature.

The vapors of other liquids have less latent heat than water, as is shown in the following table:

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31. Give the second proof.

32. To what is the value of steam, as a source of heat, owing? Explain Fig. 12. How do the latent heats of other liquids compare with that of water?

Vapor of Water,	966·924.
" Alcohol,	374·958.
" Vinegar,	183·438.
" Ether,	163·998.
" Turpentine,	123·714.

33. *Steam.* All the properties of steam have been very carefully studied on account of its vast mechanical power, and its exceedingly numerous and valuable applications in the arts. As the description of the *steam engine*, belongs more properly to mechanical philosophy, than to chemistry, it will be omitted in this work. (See Olmsted's Natural Philosophy.) The leading properties of steam may be included under the following heads.

1. *Steam is only about half as heavy as air, and the specific gravity of watery vapor, or vapor produced at a temperature below the boiling point, is much less, varying with the temperature at which it is formed.* The specific gravity of watery vapor at different temperatures, is shown in the following table:

Temp.	Sp. gr. (air being 1000.)
32°	5·690.
50°	10·293.
60°	14·108.
100°	46·500.
150°	170·293.
212°	625·000.

At 212°, therefore, or the boiling point of water, its vapor, or steam, is a little more than half as heavy as air.

(2.) *The elastic force of steam, or watery vapor, at the common pressure of the atmosphere, is* 15 *pounds to the square inch*. This is evident in the case of steam, for when issuing from a boiler, it will force out the air from the boiler, or from any cylinder with which it may be connected, thus overcoming the pressure of the atmosphere, which is 15 pounds to the square inch. This pressure is owing to the mutual repulsion of the particles, (p. 11.) which is caused by the elevation of their temperature.

(3.) *When heated in a confined situation over water, the elasticity of steam is very rapidly increased, and is thus rendered superior to any other mechanical force within our control.*

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33. What is the first of the leading properties of steam?—the second? How is this proved? Give the third leading property of steam.

34. *Evaporation.* Natural evaporation is that process by which vapor rises spontaneously from fluids. Operating upon the entire waters of the globe, it is a most powerful agent in the economy of nature. The quantity that rises from an acre of land, varies according to circumstances. Over land covered with dry grass, in the heat of summer, it has been estimated at 1600 gallons, and on moist grounds, it has amounted in some instances, to 5,000 gallons. A circular area of *snow,* five inches in diameter, lost 150 grs. between sunset and sunrise, and 50 grs. more before night. In this experiment, the snow was exposed to a smart breeze upon a house top ; an acre of snow exposed to a similar breeze, would lose in the same time, 66,000,000 grains, or 11,111 pounds of moisture. During the night, about 1,000 gallons of water would be raised from an acre of snow. The ocean loses many millions of gallons hourly by evaporation.

35. The circumstances most favorable to evaporation are the following.

(1.) *Extent of surface.* This is true also in vaporization, or in boiling down liquids ; the vaporization of water in a flask, for instance, will proceed much faster when the water is half boiled down, than when the flask is nearly full, because a greater extent of surface is exposed, and the same water in a wide evaporating dish, will boil away much quicker than in a deep one.

(2.) *A free current of air.* When the air rests on the surface of the fluid, that portion next to the surface of the fluid, soon becomes saturated, and, unless a fresh portion be supplied, the evaporation will be greatly retarded. But if, as fast as the air above becomes saturated, another portion supplies its place, the evaporation will be rapid. In an open vessel, the evaporation will be much greater than in a flask, which exposes an equal surface of the liquid, and in the open air than under the cover of a building.

(3.) *Agitation.* By means of this, a greater surface is exposed, and vapor that has been imprisoned within the body of the fluid, has an opportunity of escaping.

(4.) *A dry state of the air and an elevated temperature.* A certain amount of moisture is *due* to every temperature, and as the temperature is raised, this amount is very greatly

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34. How is evaporation defined? What is said of its extent?

35. What are some of the circumstances which are most favorable to evaporation? What examples are mentioned under the first head? Why does a free current of air promote evaporation? Why is evaporation promoted by

increased. When the air is dry, the force of evaporation to supply the deficiency of watery vapor, is very great, and, like the force with which air rushes into a vacuum, this diminishes with the supply, until, when the quantity due to the temperature is nearly supplied, the evaporation is very slow. The same process is observed, when gases are absorbed by water, or watery solutions. The force of absorption diminishes, till near the point of saturation it becomes very slow.

How important is the broad expanse of water upon which we look with so much pleasure! Even the wide surface of the ocean, added to that of all the rivers and lakes, is not too great to afford sufficient water for vegetation on land, and for copious, unfailing springs to support animal life. The surface of the ocean is broader towards the equator than in the temperate zones; and hence, as well as from the greater heat of this region, a greater amount of evaporation is produced, and consequently much more rain falls on the central portions of the earth.

36. The effects of evaporation are of the most important character.

(1.) *Evaporation renders salt water fresh.* Pure water rises from the sea in clouds, which are carried over the land, where they deposit their moisture. Were not this the case, it is evident that the vapors which come from the ocean would soon impart their saltness to all the waters of the globe, and a stream of fresh water would be unknown, much less that great abundance of pure water which we now have, and which is necessary to our existence.

(2.) *Evaporation produces cold.* This is the great agent which nature employs to check the excesses of solar heat, since this heat itself is made to generate vapor with a rapidity proportioned to its intensity; this vapor converts sensible into latent heat, during its formation, and thus maintains a perpetual check upon the violence of the sun's rays. Among the contrivances of art, none is more admirable than the *governor* of the steam engine, by means of which the flow of steam from the boiler is regulated, exactly according to its amount and pressure; but in this con-

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agitation—by a dry state of the air, and an elevated temperature? What is said of the importance of the ocean, and lakes, and other broad surfaces of water?

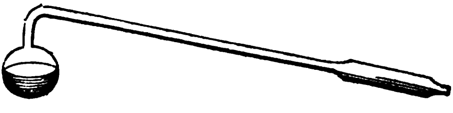
36. What are some of the effects of evaporation? Why is the first important?—the second? How does evaporation regulate the heat of the body?

trolling force of nature, a power of escape is afforded to the heat of the earth, which increases *with much greater rapidity than the heat itself,* that the moderate heat which animal life can endure may not be exceeded.

Evaporation also tends to regulate the heat of the human system. From every part of the body, moisture is continually given off through the pores, and a vast quantity is exhaled from the lungs. Perspiration, which is greater in warm than in cold weather, keeps the body nearly at a uniform temperature whatever be the state of the atmosphere. Indeed the human system has been exposed to a heat considerably above that of boiling water, without injury, so effectually did evaporation from perspiration protect it. The circulation of the blood and perspiration are in continual equilibrium in the human system; what effects the one affects also, in an equal degree, the other. Violent action or excitement, quickens the circulation of the blood, and also greatly increases the amount of perspiration.

37. Vapor of water exists in the atmosphere at all times and in all situations, but the proportion depends on the temperature, and is subject to great variation. If the air be fully charged with moisture, then the slightest reduction of temperature will cause a precipitation of a portion of the moisture. Hence, in a warm and sultry day, a tumbler of cold water is often covered with moisture, which it derives from the atmosphere immediately around it. Were the temperature of the tumbler sufficiently reduced by ice water, or a freezing mixture, it would always precipitate moisture from the atmosphere. In a clear cold day of winter, it would be necessary to reduce the tumbler many degrees below the freezing point, and the moisture would then be precipitated in the form of frost. The temperature at which moisture begins to be precipitated from the atmosphere is called the *dew-point.* It often becomes a matter of great importance to ascertain the dew-point in connection with other experiments on the atmosphere. The principle of the *cryophorus,* or frost-bearer, of Dr. Wollaston, (Fig. 13,) is applied to the

Fig. 13.



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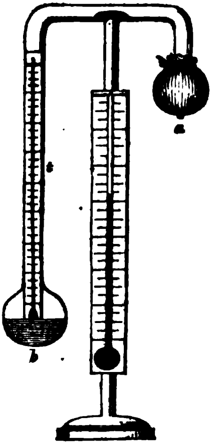
37. Why is a tumbler covered with moisture in a warm day? How is the dew point defined? Explain Fig. 13.—Fig. 14.

instrument represented in Fig. 14, the object of which is to determine the dew point easily at any time. The original cryophorus (Fig. 13.) consists of a glass tube, with a bulb at one extremity, and the other extremity enlarged, drawn out to a point, and hermetically sealed. The bulb contains a small quantity of water, the rest of the tube being a vacuum, or containing only the vapor of water. When the empty extremity of the tube is plunged into a mixture of snow and salt, the watery vapor within the tube is condensed, and this condensation gives rise to fresh evaporation from the water in the bulb, which being condensed as fast as it comes over, the evaporation goes on so rapidly from the water in the bulb, that it is soon frozen.

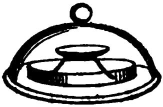
Fig. 14.



The *dew-point hygrometer* (Fig. 14.) is constructed on this principle. The bulb, *b*, is half filled with ether; *t* is a delicate thermometer *within* the tube, which dips into the ether and thus indicates its temperature, and that of the bulb in which the ether is confined. The air is excluded from the tube and both bulbs. On the stand is a second thermometer, which serves to show the temperature of the air. The upper bulb, *a*, is covered with a bit of muslin. To use the instrument, the liquid is first of all transferred to the lower bulb, and the upper bulb, *a*, and the tube then contain only the vapor of ether. The bulb, *a*, is now cooled to a very low temperature; not by a freezing mixture, as in the last case, but by the evaporation of ether, which is dropped on the muslin by which it is covered. The vapor of ether within the bulb is in this manner condensed, and this condensation in part relieving the pressure in the tube, and upon the surface of the ether in the other bulb, gives rise to fresh evaporation, and thus the process is rapidly carried on, until the bulb, *b*, by the evaporation of the ether which it contains, is reduced down to the temperature of the dew point. This is known at once, from the precipitation of moisture or frost on the outside; and at this point the thermometer within the bulb indicates its temperature, while the thermometer on the stand indicates the temperature of the air. The comparison of these two thermometers, therefore, gives the difference between the dew point and the temperature of the air.

38. Water may be frozen in the vacuum of an air pump, as well as in that produced by the condensation of its own vapor, (as in the cryophorus.) If some water in a watch glass, (Fig. 15,) be placed in an exhausted receiver, with a large surface of sulphuric acid, as fast as the vapor rises, it is absorbed by the acid, and thus a rapid evaporation promoted, until the water becomes frozen. After the receiver has been exhausted, the absorption of the watery vapor by sulphuric acid maintains the vacuum.

Fig. 15.



39. The ground at night becomes a cold surface, on which dew is deposited, exactly as it is on a tumbler of cold water. The earth radiates its heat into space, and, receiving no more from the sun, it soon becomes cold; in this state, warm air passing over its surface, becomes chilled and deposits its moisture. This phenomenon, however, would take place were the air not present, for a *certain temperature has a certain amount of moisture due to that temperature*, and when the temperature is lowered from any cause, with or without the pressure of the atmosphere, the moisture is precipitated. In the same manner, when the temperature is elevated, with or without the pressure of air, water rises in vapor.

40. If a thermometer be placed on the ground at night, and another a few feet above, the one on the ground will sink several degrees lower than the other. Some objects will be found, on applying the thermometer, much colder than others, as a stone pavement, a clay soil, or green grass, than dry straw, bricks, or a sandy soil. As dew depends on the coolness of the surface, more is therefore deposited on young green plants, than on rocks or on the soil, and on large bodies of water, as the ocean, which do not become colder at night than the air above, no dew falls. Even the dew-drops are economized by Nature.

41. Clouds hinder the formation of dew, by reflecting back to the earth the heat radiated from its surface, and

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38. Explain Fig. 15.
39. What is the cause of dew?
40. Why is more dew deposited on young green plants than on the soil? Why is there no dew on the ocean? Is dew distributed without waste? What examples illustrate this? Ans.—Dew is distributed on green grass, but not on dry hay; on young grain, but not on ripe crops; on the meadow, and the young plants of the garden, but not on the ocean.

thus preventing the necessary reduction of temperature, and the same effect is produced by a screen of the thinnest material, stretched at a little height above the ground. In this manner, gardeners often preserve delicate plants from destruction, by the frosts of spring and autumn. Winds also effectually prevent the deposition of dew, by constantly renewing the air lying upon the earth, before it has had its temperature sufficiently reduced, to cause condensation of its moisture. A clear, calm night, succeeding a hot day, is therefore that which is most favorable to the deposition of dew, for in this case, the quantity of vapor in the air is usually very great, and at the same time, radiation proceeds with the greatest facility.

DISTRIBUTION OF HEAT.

42. For the safety of the world there is impressed on heat a most powerful tendency towards an equilibrium. Whether coming from the sun, or produced by artificial fires, the heat of any particular place is no sooner increased above that of the surrounding medium, than the excess endeavors to make its escape in every way, and can be retained only by the greatest pains and skill, even for a few moments. All objects around us, are naturally of the same temperature, and the heat of the equator is soon dissipated towards the poles. By four methods heat is distributed,—*by radiation*, *by reflection*, *by conduction*, and *by convection*.

43. (1.) Radiation is *the emission of heat in right lines from the surfaces of bodies.* From reflection, it differs in the source or origin of the heat which is emitted, which in radiation is from within the body, but in reflection, is from without the body. A body radiates its own heat, and loses heat by radiation, but reflects the heat of other bodies from its surface, and therefore, sustains no diminution of temperature by reflection.

44. The sun and all ignited and burning bodies, afford the most striking examples of the radiation of heat, although all hot bodies, as hot stoves, steam boilers, &c., likewise radiate heat.

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41. How do clouds hinder the formation of dew?—wind? Why is a clear, calm night, succeeding a hot day, most favorable to the deposition of dew?

42. By what four methods is heat distributed?

43. How is radiation defined? How does radiation differ from reflection? Why does a body lose heat by radiation? Why does it lose no heat by reflection?

44. Mention some examples of bodies that radiate heat?

45. The power of radiation depends greatly on the *nature of the surface.* It proceeds much more rapidly from a rough surface than a smooth one, and from a black surface, than from one of any other color, and least of all, from a white surface.

The following experiments performed by Dr. Stark of Edinburgh, show the connection which exists between the power of radiation and the color of the surface. The bulb of a delicate thermometer was successively surrounded by equal weights of differently colored wool, then placed in a glass tube, heated by immersion in hot water to 180°, and finally cooled to 50° in cold water. The times of cooling were 21 minutes with black wool, 26 with red wool, and 27 with white wool. Similar results were obtained with flour of different colors. Likewise, black wool was found to collect more dew than an equal weight of white wool, other circumstances being alike. If pieces of cloth of various colors, also a plate of a bright and one of a dark rough surface, be exposed during the night, in the morning the black cloth and the dark rough surface will be found to have the most dew, while upon the white cloth little dew, and upon the bright metallic surface, none will be deposited.

46. *Bodies that absorb most heat, radiate most, although the amount of absorption and radiation, are not always proportional to each other.* Snow melts more rapidly when soot or dark earth is scattered upon it, because it then absorbs heat more rapidly from the sun. Grapes and other fruits ripen quicker against dark walls, than those having a light color, because these walls absorb heat, which they communicate to the grapes and the air by which the grapes are surrounded. If the bulb of a thermometer be covered successively with different colored wools, and exposed within a glass tube to hot water, the thermometer will rise most quickly when covered with black wool; more slowly when covered with green wool; slower still with scarlet; and slowest of all with white. If three tumblers be enveloped,

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45. Upon what does the power of radiation greatly depend? What experiments were performed by Dr. Stark to show the connection between the power of radiation and the color of the surface? Which color is found to produce the greatest deposition of dew? Why is most dew deposited on a black surface? Ans.—Because this radiates most rapidly the heat of the earth, and, therefore, becomes colder than a surface of any other color. Why is no dew deposited on a bright metallic surface? Ans.—Because this does not radiate the heat of the earth, and therefore does not become sufficiently cold for the deposition of dew.

46. How are absorption and radiation related to each other? Mention some examples showing the effect of color on absorption.

one with silver paper, another with white, and another with dull black paper, and all be placed in the sun, a thermometer will indicate that the tumbler with black paper, absorbs most heat in a given time, and that with the silver paper, the least.

47. The following rules for the practical management of heat, are derived from the foregoing principles.

For confining heat, no surface is so effectual as a bright metallic one. This also should be as smooth as possible, for the minute points and edges of a rough surface dissipate the heat rapidly. Among the various colors, white is the best for confining heat; hence white houses are warmer in winter than those of a darker color, as the loss of internal heat by radiation, is not so great from these as from other houses; they are also cooler in summer, as they absorb less heat, or reflect more. Pipes intended for conveying heat to distant apartments, should be bright and smooth, but those intended for warming a room, should be rough, like sheet iron.

We may regulate our apparel on the same principles. If we are to expose ourselves to the sun in hot weather, white clothes should be selected, as white absorbs less heat, or *reflects* more than any other color. If we are to continue in the shade, black garments are more suitable, as black *radiates* heat more than any other color.

48. The power of absorbing heat, possessed by cloths of different colors, was tested by Dr. Franklin in the following manner. He took pieces of cloth of four different colors,—black, blue, brown and white, and laid them on the snow, in the direct rays of the sun. After a few hours, it was found that the black had sunk to a considerable depth, the blue not so far, the brown still less, and the white hardly at all. From this experiment, it was inferred that black is the warmest color in the sun, or absorbs the most heat; blue the next; brown absorbs less heat than blue; and white is the coolest of all the colors. In the cold days of winter, therefore, when the heat of the body escapes most rapidly, a white overcoat is to be preferred, to check the loss of heat by radiation. This color is chosen by Nature, when she

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47. What is the first rule for the management of heat derived from these principles? Why are white houses warmer than those of a darker color? Of what should pipes, intended for conveying heat, be made?—for diffusing heat? What clothes are most suitable for wearing in the sun during hot weather?—in the shade?

48. Mention the experiments tried by Dr. Franklin. What is the warmest

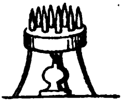
wraps the Northern hemisphere with a mantle of snow, or clothes the animals of the frigid zone for the intense cold of their winters. Some of these animals even change their color at the approach of winter, as some varieties of the hare.

49. *Reflection* is, like radiation, the emission of heat from bodies in right lines, but it differs from the latter, in the source of the heat, which is from without, or external to the body causing reflection. That bodies which absorb the most heat, must reflect the least, is evident, for all that is absorbed is, of course, taken from that which is reflected. Absorption and reflection are therefore opposite. Reflection and radiation are also opposite, for, as stated above, bodies that absorb most also radiate most. If, therefore, a body radiates more than another body, we know that it also absorbs more, but reflects less. All the rules given above, for radiation and absorption, will, if reversed, apply to reflection.

50. *Conduction is the propagation of heat through the substance of bodies.* This passage of heat through some substances, is much more rapid than through others. Accordingly, bodies are divided into conductors and non-conductors of heat. The former are those that conduct heat readily; the latter, those that conduct heat with difficulty, or not at all. Among the conductors, are the metals and stones. Perhaps there is no absolute non-conductor of heat, unless the air, and some of the gases, be considered as such; but in this class are included such bodies as bricks, wool, feathers, most of the liquids, and the gases.

If two similar rods, one of iron and the other of glass, be held in the flame of a spirit lamp, the iron will soon be too hot to be touched, while the glass can be held within an inch or two of the red-hot portion.

Fig. 16.



51. The different conducting powers of several substances, may be illustrated by little cones (Fig. 16.) of copper, iron, wood, &c., placed on a double metallic plate, which is heated by a lamp from beneath. The heat is uniformly distributed over the upper plate, by the heated air which rises from the lower, and is therefore communicated to

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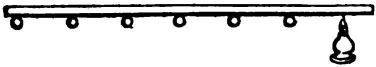
garment for winter? What is said of the snow and the animals of the Frigid Zone?

49. How is reflection defined? How are absorption and reflection related? Why are reflection and radiation opposite?

50. How is conduction defined? What is meant by conductors and non-conductors of heat? Mention some examples of conductors;—some examples of non-conductors. What experiment illustrates the conducting power of iron and the non-conducting power of glass?

the bottom of all the cones alike. The heat, however, rises to the summits of these cones at very different rates. If a ball of wax be placed on each of these summits, on the copper cone the wax will be melted first, and the ball will drop off; on the iron the next; while on the wood the wax will remain unmelted. If bits of phosphorus be placed on the cones, they will be fired in the same order of copper, iron, &c.

Fig. 17.



If several marbles be stuck with wax on a copper wire, (Fig. 17.) and one end of the wire be held in the lamp, as the heat travels through the wire the marbles will drop off one after another.

52. In the following table are given the relative conducting powers of several substances, gold being 1000.

Gold,	1000.	Zinc,	363.
Silver,	973.	Tin,	304.
Copper,	898.	Lead,	180.
Platinum,	381.	Marble,	23·6.
Iron,	374.	Porcelain,	12·2.

From this table, it appears that the conducting power of gold is nearly three times that of iron; that of copper is more than twice that of iron, while lead has not half the conducting power of iron. Bodies not metallic, as marble and porcelain, are much poorer conductors of heat than the metals; and fire-clay and wood, are still worse conductors. Heavy, solid wood, is a much better conductor than that which is light and porous. In the list of non-conductors, may be reckoned, dry bricks, wool, feathers, hair, fur, &c. It is owing to this property, that the latter are used for clothing, and bricks in the construction of houses. The value of this class of bodies as non-conductors, is destroyed, or greatly impaired, by the presence of moisture. Thus straw is a good conductor when wet, but a bad conductor when dry. Wet garments are unhealthy, as they carry off the heat of the body, and thus produce violent colds and fevers.

53. *Snow* is admirably adapted as a protection to the earth, (1.) by its color, which prevents loss of heat by radiation; (2.) by its non-conducting properties, as it is one of the

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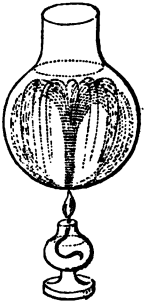
51. Explain Fig. 16.—Fig. 17.

52. How do the conducting powers of gold, copper, and lead, compare with that of iron? What is said of the conducting power of non-metallic bodies? Mention some of the non-conductors. What is the effect of moisture on these bodies? Why are wet garments unhealthy?

best non-conductors; (3.) by its light, downy texture, which causes it to fall gently to the earth, imprisoning much air between its crystals, and leaving the earth open and porous beneath; (4.) by its temperature, which is very moderate, compared with that which prevails during the coldest days of winters; hence the warmth of the snow-huts of the Esquimaux, and the protection of their springs of water, during the intense cold of their winters. The surface of the earth covered with snow, is protected at the temperature of the freezing point, and immediately below the surface the temperature is much higher. The roots of plants are preserved, and the fermentative processes of vegetable decay are carried on; the soil thus imbibing fertility in the midst of winter, and being prepared to receive the rays of the sun in spring. (5.) The latent heat of snow has already been noticed. This adds greatly to its value, preventing inundations, which would be produced by its sudden melting in spring, and retarding the too sudden approach of winter. The snow of winter is, therefore, not only its ornament but its protection, and by this in winter, Nature prepares the beauty of summer and the bounty of harvest.

54. *Convection* is that method by which heat is conducted in fluids; it may be defined, *the conduction of heat in fluids, by a motion among their particles.* The common mode in which liquids are heated, is represented in Fig. 18. A lamp is placed beneath a glass vessel, made of thin* glass. A current of hot water rises (for the particles of water, being expanded by heat, become lighter) in the center to the top, where it becomes cooled, and then descends on the sides. This process is kept up until the whole body of the water is heated. When the temperature of the water is thus raised to 212°, boiling succeeds, in which vapor, and the water which it carries up mechanically, rises in the center, and the remainder of the water descends on the sides.

Fig. 18.



55. When the water on the surface of the ocean is cooled down lower than that beneath the surface, it descends, and

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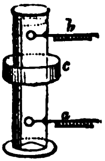
* Thick glass cracks on the application of heat, by the unequal expansion of the inside and the outside; but in thin glass, this inequality is not so great; hence, vessels made of thin glass are not so apt to crack.

53. In what ways does snow serve as a protection to the earth?
54. How is convection defined? Explain Fig. 18.

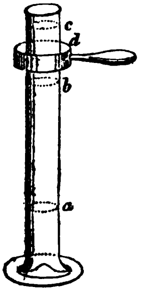
warmer portions ascend, which are cooled in the same manner. Currents also from the polar regions, flow towards the equator, and from the equator other currents flow to the northern and southern latitudes. In this way, the heat of the ocean is distributed throughout its mass, above and below, in warm and in cold latitudes. In the air, and in all vapors and gases, the same thing happens. The rays of the sun pass through transparent media, without affecting their temperature. Only those portions of the atmosphere, therefore, which come in contact with the earth, are heated. These rise, and their place is supplied by colder portions, and thus the heat of the earth is distributed throughout the atmosphere.

Fig. 19.



56. But without this convection, or *carrying process*, the conducting power of liquids and gases is very small. If a test tube, nearly filled with water, be held over a spirit lamp inclined in such a manner as to direct the flame against the upper layers of the water, the water will boil at the top, but remain cool below. In Fig. 19. a jar of water is perforated at *a* and *b*, for two thermometers, and surrounded at *c* with a metallic trough. Into this trough boiling water is poured. After some time, it will be found that the upper thermometer has risen, while the lower has remained perfectly stationary. The upper part of the fluid is heated by convection, while the lower part can be heated only by conduction.

Fig. 20.



The same principle is illustrated in a different manner, in Fig. 20. *a b c* is a tall jar, or wide tube; *d* a ring of iron provided with a handle. Into *a b c*, a little water, colored blue, is poured as high as *a;* water not colored is then added as high as *b*, and the portion from *b* to *c*, is filled with a yellow solution. If the ring, *d*, is heated red hot, and applied to the tube or jar between *b* and *c*, the yellow portion, *b c*, may be made to boil without intermingling with the colorless portion, *a b*. But if the red hot ring be lowered down, so as to surround the blue portion, it will, as it becomes warm, ascend first through the color-

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55. How is heat distributed in the waters of the ocean?—In the atmosphere?

56. What is the conducting power of liquids and gases when heat is not distributed through them by convection? How may this be shown by a test tube nearly filled with water and held over the flame of a lamp? Explain Fig. 19.—Fig. 20.

less stratum, and finally through the yellow solution at the top. If a piece of ice be suspended in the empty jar, and the red hot ring applied to the portion of the jar above, it will continue to melt very slowly, as before the ring was applied; but if the ring be carried down the jar below the ice, it will melt much more rapidly.

57. Air, by its non-conducting properties, enhances those of all other substances, and is, to a great extent, the cause of the non-conducting power of most substances. It not only surrounds all bodies on the earth, but fills the pores of almost all bodies. Were air, therefore, a good conductor, snow, wood, feathers, water, and all those light bodies which are remarkable for their non-conducting power, would become conductors, and other bodies would avail little in retarding the escape of heat, being surrounded on all sides by a good medium of transmission. Our dwellings could not be warmed, for air entering the smallest crevices, and pervading the materials of which they are constructed, would carry off the heat as fast as it was generated. The smallest dew-drops, and the vast atmosphere, are formed with the same wisdom and benevolence!

58. Applications of the non-conducting properties of air, are seen in the construction of furnaces for heating buildings, where confined air is often used to prevent the heat from escaping from the sides of the furnace. The common *refrigerator*, for keeping ice a long time without melting, is constructed with a space of confined air between the inside and outside. *Ice houses* are made with double walls, between which is placed charcoal, fine saw dust, or some other light substance; or this space is occupied merely by confined air. In northern countries, the houses are provided with double windows and doors, and thus a portion of air is confined, which effectually excludes the cold.

QUANTITY OF HEAT IN BODIES.

59. Latent heat is observed, when bodies are changing their form from the solid to the liquid, or from the liquid to the aeriform state. But another equally remarkable phenomenon of heat is observed, in the amount necessary to raise different bodies to a given temperature, even without a change of form. This is called *specific heat.* It may be illustrated in the following manner:

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57. What is said of the non-conducting properties of air?
58. What applications are made of the non-conducting properties of air?

Put as many marbles into a glass as it will contain. When the vessel is full of marbles, add as much sand as will penetrate and lodge between the marbles. Fill also another glass with pebbles, which will arrange themselves in a more compact form than the marbles. Pour sand into the second glass and it will be found to contain less than the first. In the same manner, more heat enters into some bodies than into others, to raise them to a given temperature. If, for instance, a pound of lead, a pound of chalk, and a pound of milk are placed in a hot oven, they will be gradually heated to the temperature of the oven; but the lead will attain it first, the chalk next, and the milk last.

60. Take a pound of oil at 40° and a pound of water at 100°, and agitate them together. The temperature of the mixture will not be the mean between the two, or 70°, but the thermometer will stand at 80°. Reverse the experiment, and with a pound of oil at 100° mix a pound of water at 40°; the temperature of the mixture in this case, will fall below the mean, and will be at 60°. These results may be compared numerically, in the following way.

Exp. 1. 1 lb. of water, at 100°, } give a mixture at 80°.
1 lb. of oil, at 40° (1), } Mean =70(2).

Exp. 2. 1 lb. of water, at 40°, } give a mixture at 60°.
1 lb. of oil, at 100°(3), } Mean=70(4).

From both these experiments it appears, that water has more heat at the same temperature than oil, for in the first case it raised the oil (1) above the mean (2,) and in the second case, it sank the temperature of the oil(3) below the mean(4). In the first instance, it heated the oil more than it lost heat itself; in the second, it took from the oil more than it gained itself, as indicated by thermometer. The first result was the loss of 20° by the water, and a gain of 40° by the oil; the second, a loss of 40° by the oil, and a gain of 20° by the water. We may therefore conclude, that 20° of heat in water, is equal to 40° in oil, or that the *specific heat* of water is twice that of oil; *it takes twice as much heat to raise water to a given temperature, as it does oil to the same temperature.*

61. In forming a *table* of specific heats, water is selected as a standard. With water, other liquids may be compared,

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59. What is specific heat? How does it differ from latent heat? How is it illustrated?

60. In what way may the specific heats of water and oil be compared? How much more heat does it take to raise water to a given temperature than oil to the same temperature?

by the method of mixtures given above. In the case of a solid, the same method may be adopted. If a bar of copper, of a pound weight, be heated to the temperature of 320°, and plunged into water at 70°, when both have acquired the same temperature this will be found to be 92°. This stated in numbers is as follows:

$$\left.\begin{array}{l}\text{1lb. of copper, at }320^\circ,\\ \text{1lb. of water, at }70^\circ,\end{array}\right\}\begin{array}{c}320^\circ-92^\circ=228^\circ(^1).\\ \text{Common temperature, }92^\circ.\\ 92^\circ-70^\circ=22^\circ(^2).\end{array}$$

The copper has therefore lost 228° (1), and the water has gained 22° (2). Therefore, if water was 228, the specific heat of copper would be 22, for the water gained only 22, while the copper lost 228. The number of water is, however, 1,000; therefore, the specific heat of copper must be represented by 0·096, which is obtained by the following proportion:

$$228 : 1{,}000 :: 22 : 0.096.$$

The power of different bodies to receive more or less heat, in rising to a given temperature, is called *capacity for heat;* it differs from specific heat in this:—capacity is the *power to receive*, specific heat is *that received*, and these differ in different bodies. Thus in the experiment with the tumblers (59,) the space between the marbles in the first, would represent capacity, and the sand which was poured in specific heat; in the second, the space between the pebbles would represent capacity, and the sand, as in the first case, specific heat. As the space and sand were less in the second than in the first, so capacity and specific heat are less in some bodies than in others, but in all cases correspond with each other, being greater in the same bodies, and less in the same bodies.

63. *If the capacity of bodies for heat is in any way increased, a corresponding amount of cold is produced.* This increase, or diminution of capacity, may be produced by increased or diminished pressure. In the mines of Chemnitz in Hungary, a column of water 260 feet high presses on a quantity of air in a tight reservoir. The pressure, therefore, is immense, being equal to 68 or 69 atmospheres, and when a pipe communicating with the reservoir of condensed air is

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61. In forming a table of specific heats, what is taken as the standard? By what method may the specific heats of liquids be compared with that of water?—solids? In what manner may the specific heat of a bar of copper be determined?

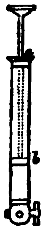
62. How is *capacity for heat* defined? How does it differ from specific heat? How is this difference illustrated?

suddenly opened, it rushes out with extreme velocity, instantly expands, and, in so doing, absorbs so much heat, that the moisture which it holds is precipitated in the form of snow. In this case, the capacity of the air for heat was diminished by the condensation in the air chamber. Watery vapor, therefore, remained suspended in this condensed air without loss of heat. But the moment that the pressure was removed, the capacities of both the air and the watery vapor for heat were vastly increased, both of which would lose in sensible heat, in proportion as they gained in capacity, and thus the vapor, and the jet of water would be frozen, the former in the form of snow, the latter in that of ice.

When steam issues from great pressure it does not scald as at common pressures, although its temperature *while under pressure* was much higher than 212°. When set free, its capacity is so suddenly enlarged as greatly to lower its temperature. The diminished capacity for heat of steam under great pressure, renders it more profitable to employ this kind of steam, or *high steam*, than steam at low pressure, or *low steam*. Still the latter is generally preferred, being less liable to accident.

64. On the other hand, by sudden condensation, a great degree of heat may be produced. Fire may be produced by the sudden condensation of air. In Fig. 21, *a* is a piston moving air tight in a cylinder, *b*. On the end of the piston there is a cavity, in which a piece of tinder is fastened. When the piston is suddenly forced down, the condensation of the air causes so much heat as to set the tinder on fire. Before better means of obtaining fire were found out, these instruments were used for that purpose.

Fig. 21.



65. The quantity of heat which bodies contain, as indicated by the thermometer, is called their *temperature*. This term, therefore, applies only to sensible heat. The temperature of bodies cannot be accurately determined by our sensations. This may be shown by the following experiment—*a*, *b*, and *c*, (Fig. 22.) are three bowls, of which, *a* is filled with hot water, *b* with water at the common temperature, and *c* with

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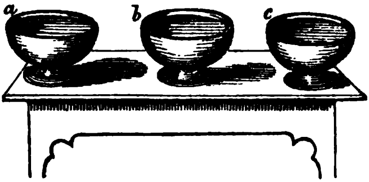
63. What is the effect of increasing the capacity of bodies upon their temperature? How may an increase or diminution of capacity be produced? How is this shown in the mines of Chemnitz? Why is the temperature of high steam less than that of low steam, when set free? Is high or low steam economical? Why is not high steam generally employed?

64. What is the effect of diminishing the capacity of bodies? Explain Fig. 21.

65. How is temperature defined? Explain Fig. 22.

cold water. If the left hand be placed in *a*, and the right hand in *c*, and, after some time, both hands be removed to *b*, to the left hand, the water in *b* will appear cold, but to the right hand it will appear warm, or even hot.

Fig. 22.



66. A good conductor, as a metal or a stone, appears much colder than a bad conductor, as a brick, or dry wood. A day in winter, when the thermometer is at 50°, feels warmer to us than one in summer when the thermometer is at 60°. In judging, therefore, of the amount of heat in bodies at common temperatures, we use the thermometer, and in measuring intense heat, the pyrometer. From these instruments we learn,—

(1.) *That all bodies in the same vicinity, and not exposed to the direct rays of the sun, are maintained continually at the same temperature.* Those also which are in the direct sunlight, as soon as the sun's rays have left, are reduced to the same temperature with other bodies, and the temperature of distant regions is rendered more equal by currents of air, and by radiation and reflection of heat.

(2.) *The whole range of natural temperature is exceedingly small, compared with the extremes of heat and cold, which have been obtained by artificial means.* More than 25,000 degrees have been estimated, from the greatest cold to the highest heat yet obtained, and it is in the power of the chemist, by means of instruments to be described hereafter, to produce a heat vastly more intense than this. Yet the range of *natural temperature* hitherto discovered, is less than 200 degrees. The greatest heat hitherto discovered, in a situation completely protected from the sun's rays, is that by Belzoni, in a cave in Egypt, where the thermometer rose to 120°. The greatest cold was observed in Siberia, where the thermometer sunk to 70° below zero. One hundred and ninety degrees, we may therefore receive as

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66. By what two instruments is the amount of heat in bodies measured? What is said of the temperature of bodies in the same vicinity? How does the whole range of natural temperature compare with the extremes of heat and cold obtained by artificial means? How many degrees of heat have been estimated from the greatest cold to the highest heat yet obtained? What is the range of natural temperature hitherto discovered? What is the greatest heat? —the greatest cold?

the entire space occupied by natural heat in the scale of temperature. Much less is the range which man can endure with comfort, or with prolonged life. Many of the islands of the sea, do not differ but 20 degrees in the entire year, and sometimes not more than 10 degrees.

67. The most important circumstances affecting our sensations of temperature, are the following:

(1.) *A dry air feels much cooler than a moist air at the same temperature, because it cools us by evaporation of moisture from the surface of the body.* A moist air being already charged with vapor, checks the evaporation from the surface, and thus appears to be much warmer than it really is.

(2.) *Good conductors of heat, feel much colder than non-conductors, because they carry off heat more rapidly from the system.* Thus an iron knob feels much colder than a wooden or glass handle. Jewellers in this way at once distinguish jewels from imitations, by touching them to the tongue. The real jewel is known by its coldness. A mass of rock-crystal may at once be known from glass, by placing the hand upon it.

(3.) *A situation where the air circulates freely, is much cooler than are others where it is still, although the thermometer may indicate no difference.* From all bodies that are warmer than itself, air in motion carries off heat more rapidly than still air, for new portions of air are continually brought into contact with the warm or heated surface. This is especially true of the body, which is not only exposed to a greater amount of air, but loses a greater quantity of moisture when the air is in motion, and this increased evaporation carries off a great amount of heat.

(4.) *Clothing enables us to endure the severity of winter, by preventing the escape of our heat.* The inhabitants of the central regions of the earth wear little clothing, and that of a nature to intercept but little of the heat of the body. In temperate latitudes, during winter, the inhabitants clothe in woolen garments, which confine the heat more perfectly than cotton or linen; and in more northern countries, the dress consists to a great extent of furs, which are much better non-conductors than woolen garments.

(5.) *In all the seasons of the year, particular provision is made for the welfare of man.* In *winter*, the congelation of

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67. What is the first cause which affects our sensations of temperature?—the second?—the third? Why does clothing enable us to endure the severity of the winter? How is the welfare of man consulted in the different seasons?

great masses of ice returns to the air vast quantities of latent heat. As *spring* advances, the melting of the snow keeps back the too sudden return of summer. In *summer*, the vast amount of evaporation which takes place, reduces to a great degree the temperature of the air. Finally, in *autumn*, the condensation of vapor protracts the duration of summer, and retards the sudden coming on of winter.

68. At a certain distance above the earth, we come to the region of perpetual frost. The loftiest mountains are covered with snow, which continues the entire year, and is never melted. The lower limit of this region is called the *Term of Congelation*. This term varies in height in different latitudes, being about three miles at the equator, and descending to the general level of the earth at the poles. The intense cold of the air of these elevated regions, arises from two causes ;—

(1.) *The sun's rays penetrate through the atmosphere without heating it.* Even at the equator, the air is heated chiefly from the ground, which receives the heat from the sun, and communicates it, by *contact*, to the air. This fact accounts for the intense heat of deserts, where no evaporation takes place to cool the surface, but the heat accumulates on the sands. When we ascend above the general level of the earth, as we leave the source of heat, the air becomes gradually colder, until at the height of the highest mountains we come to a region of intense cold.

(2.) *The air of these regions is greatly rarefied.* This cause operates to increase the capacity of the air for heat (61.), and thus it absorbs heat from the mountains with which it is in contact, producing a temperature below the freezing point, on the same principle that snow is produced by the sudden expansion of air in the mines of Chemnitz.

SOURCES OF HEAT.

69. The chief sources of heat are the following:

(1.) The Sun.
(2.) The interior of the Earth.
(3.) Combustion.
(4.) Percussion.
(5.) Friction.
(6.) Mixture.
(7.) Electricity.

70. (1.) The sun is the great source of natural heat, and its place in the heavens is so adjusted, that were it any

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68. What is the Term of Congelation? To what two causes is the intense cold of the air of elevated regions owing?
69. Mention the chief sources of heat.

further removed from us, or any nearer to us than it is, "the world would return to its original chaos." The amount of solar heat is not accurately indicated by the thermometer, for we cannot place this instrument in a situation exposed to the sun's rays, where it will not lose most of the heat which falls upon it, by radiation, conduction, currents of air, &c. Were we able to confine all the heat which comes to it from the sun, we should find that this heat greatly exceeds what we are accustomed to consider as its amount. By surrounding the thermometer with non-conductors, it has been made to rise in the sun higher than 237 degrees. Hence we see the reason why in warm countries it has been considered hazardous to venture abroad in the open sun at noon-day, without an umbrella or some protection from the direct rays of the sun.

71. (2.) A second source of heat exists in the interior of the earth. It is found, in sinking mine shafts, boring for water, &c., that, in descending, the temperature rises 1° for every 45 feet, or 117° per mile. If the rise of temperature continue at the same rate, at the depth of less than two miles the earth has the temperature of boiling water; at nine miles it is red hot, and at thirty or forty miles depth, all known substances are in a state of fusion. We are standing upon a crust, and nearly all the four thousand miles from us to the center of the earth, is a melted mass, which frequently pours forth lava from volcanoes, or rumbles in earthquakes, when it comes in contact with water or other substances that produce violent action.

72. (3.) Combustion is the most common and diversified source of heat. By his control over the process of combustion, man has arisen to his present high state of civilization. By this he evinces his superiority to other animals, and asserts his dominion over matter. Instinct has not failed to teach the lower animals all that their situation required,—to build dams according to the most perfect rules of architecture, to construct nests with wonderful skill, and to understand and imitate man in his voice and actions; but to employ the energies of heat in subduing matter, in moulding metal, in excavating rock, and in accumulating power which nothing can resist, is exclusively the prerogative of man.

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70. What is said of the heat of the sun?
71. What is said of the heat of the interior of the earth?
72. What is said of combustion?

The variety and beauty of combustion may be well illustrated by pyrotechnic compositions, some of which will be found in the sequel(2).

73. (4.) Percussion produces heat on a limited scale, as in the hammering of iron, and in the coining of money. The rise of the temperature in this case, is owing to the condensation of the matter in the substance which is pounded, and is in proportion to the degree of that condensation. A bar of metal, after it has heen heated by pounding, becomes brittle, but recovers its malleability after being heated in the fire. From this fact it is inferred, that the heat which was extricated by hammering was combined with the metal, and was the cause of its malleability. In the percussion of steel and flint, so much heat is produced, that the particles of steel are set on fire, producing what is called, "striking fire with steel."

74. (5.) Friction is another familiar source of heat. Savages kindle fires by rubbing pieces of dry wood together, and dry forests are sometimes set on fire by the motion of one limb upon another. The sides of a ship are said to take fire by the rapid descent of the cable, and the axletrees of carriages are set on fire by rapid motion. Two pieces of ice have been melted by friction against each other in a vacuum at 32°. The water in which cannon are bored is sometimes heated to the boiling point by the friction of the borer against the metal which it cuts. All machinery, therefore, where there is much friction, must be moistened or lubricated to diminish the heat. Disastrous consequences often ensue from inattention in this respect.

The heat excited by friction may be classed as an effect of condensation, since the surfaces exposed to friction are subjected to constant compression. This heat is not in proportion to the hardness and elasticity of bodies, for a piece of brass rubbed with cedar wood produces more heat than when rubbed with another metal, and the heat is still greater when two pieces of wood are rubbed together.

75. (6.) The mixture of two or more substances which act chemically upon each other, is almost always attended with a change of temperature(3). In all these cases, where heat is evolved, the mixture occupies less volume than the components, and the heat is owing to this condensation. In mixing sulphuric acid and water, the condensation may be

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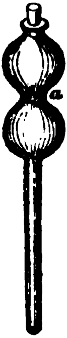
73. What is said of percussion?
74. What is said of friction?

made apparent by the method represented in Fig. 23. *a* is a tube with a double globe. The stem and one bulb is filled with strong sulphuric acid, and the upper bulb with water. It is now corked and inverted. The water rises to mingle with the acid, and the diminution of volume will be seen in the tube. In dissolving salts, which contain a large amount of the water of crystalization in their composition, this water is set free, and the volume is thus considerably increased. The solution of these salts, therefore, produces cold, and this is one cause of the cold produced by freezing mixtures; but if these salts be previously deprived of their water by exposure to heat, and then dissolved, heat is produced, because they combine with a portion of the water, and the volume of the two becomes condensed.

Fig. 23.



76. (7.) Electricity affords the means of exciting a heat as powerful as any that is known. The particular mode in which this is effected will be decribed hereafter under the head of galvanism.

LIGHT.

77. This subject must be studied chiefly under Natural Philosophy, which takes cognizance of the mechanical means by which it is decomposed, its laws, which are chiefly mechanical, and the phenomena that are produced by these laws. A few of the *leading facts and properties* of light only belong to Chemistry. Among these are,

(1.) *Its composition. Light is not a simple substance, but is made up of three kinds of rays.* These three kinds are called the calorific, (Latin *calor*, heat,) or heating rays; the colorific, or coloring rays; and the chemical rays. In every beam of light these three kinds of rays are united. The colorific rays are found to be seven in number, viz: violet, indigo, blue, green, yellow, orange, and red. The

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75. What is said of mixture?
76. What is said of electricity?
77. What is said of the composition of light?—its chemical effects? What are some of the effects of light in the animal kingdom?—in the vegetable kingdom? What is said of the light from different bodies? How many of the

method of decomposing light is entirely mechanical, and therefore belongs to Natural Philosophy.*

(2.) *Light produces on many bodies true chemical effects, causing an entire change of properties.* It will be seen hereafter, that two gases, chlorine and hydrogen, combine at common temperatures only under the influence of light; and when the direct rays of the sun fall upon their mixture in a glass bottle, they unite with explosion sufficient to burst the bottle. The chemical action of light is essential to both the animal and vegetable kingdom. In the animal kingdom the effect is most apparent in changing the color to a darker shade. When persons are secluded from the light, they become pale and sickly; when sufficiently exposed to the light, they assume a ruddy and healthful complexion. Certain animal substances, however, are bleached by exposure to the light. Thus the hair of children is rendered white by playing in the sun, candles are whitened by hanging at the windows, and beeswax is bleached by being spread on ribbons and exposed to the sun. Oil is clarified by light, and woolen stuffs are faded or bleached by a similar process.

The vegetable kingdom exhibits the effects of light in a much higher degree. Plants that grow in the shade are slender, pale, and sickly, destitute of taste, odor, and all their peculiar properties. When a vegetable grows in a dark place near a wall, if a small opening be made in the wall, the plant will turn towards it, make its way out, change its sickly hue to a lively green, and speedily acquire all its characteristic properties. If to that portion which still remains in the dark a light be supplied from a lamp, the same effect will take place upon this as upon that portion without the wall, exposed to daylight. On this principle gardeners secure celery and cabbage from the light, to give them tenderness and whiteness. The potato, exposed to the light, becomes green, rigid, and bitter. Rose bushes that bear red roses in the light, bear white roses when made to grow in the dark.

The art of *Daguerreotyping* depends on the chemical agencies of light. This process will be described hereafter, when the substances which are employed in it are understood,

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* See Olmsted's Natural Philosophy, where many new and beautiful experiments illustrating the composition of light are described.

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primary colors are contained in the white light of burning charcoal? How many in the Drummond light? Of what does the light emitted by iron, at a dull red heat, chiefly consist? What is said of the light of double stars?

(3.) *Light from different bodies differs in color.* The white light of burning charcoal is the principal source of the light from candles, oils, and the illuminating gases, for it is the carbon which these flames contain that burns in the light, and gives intensity to the flame. This light, when analyzed, gives only three of the primary colors, red, yellow, and green. The dazzling light emitted by lime, in the Drummond light, produces the prismatic colors almost as brightly as the sun. The light emitted by iron at a dull red heat, consists chiefly of the blue and red rays. It is also a fact of great interest, that, while our sun gives white light to the bodies of the planetary system, there are stars or suns of different colors, which illumine the worlds upon which they shine with different colored light at different times. These stars are called double stars. The colors of two stars which together form a double star, are such that when united they form white light.

(4.) *All bodies emit light at a high heat, and many at the ordinary temperature.* When the temperature of solid substances is raised to about 1000°,* they begin to be luminous in the day light. It requires a far higher temperature to render a gas visibly ignited. This may be illustrated by holding a piece of platinum-wire in the current of air which rises from a spirit lamp; the air is not visibly ignited, but the wire instantly becomes red-hot. Many bodies phosphoresce, or give out light at the ordinary temperature. The diamond, when slightly heated, rubbed, or compressed, emits a light almost equal to that of the glow-worm. A variety of the sepia, found in the Mediterranean and Indian seas, is said, when opened, to exhibit so brilliant a light as to illuminate a large room. The following fluids were found by Dr. Brewster to be phosphorescent when poured into a cup of heated iron;—albumen (white of an egg) diluted with water, isinglass in solution, saliva, soap and water, solution of rhubarb, common salt or nitre, tallow, alcohol, oil of dill-seeds, and oil of cloves.

Several *plants* have been observed to be luminous in the dark. But the finest example of phosphorescence is that of the ocean. Here the waves that surround the ship are illu-

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* There is considerable difference in the temperature of ignition among solid bodies. Metals generally become luminous at a lower temperature than other bodies.

What takes place at a high heat in all bodies, and at the ordinary temperature in many? What is said of the ignition of gaseous bodies? Mention some examples of phosphorescent bodies.

minated, as far as the eye can reach, with innumerable bright spots of light rising to the surface and again disappearing, like a host of small stars dancing and sparkling on the bosom of the sea. Sometimes, also, large globes of fire are seen, mostly at a great depth, shining through the water, then rising rapidly to the surface and flashing a bright spark of light, so brilliant as almost to dazzle the eye, and again they float along, disappearing gradually with the dark water in the distance. All this light comes from animalcules, for, after being caught in vast numbers, they have continued to give out light.

GALVANISM.

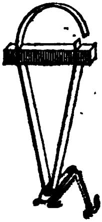
ELECTRICITY OF CHEMICAL ACTION.

78. Common electricity and magnetism are generally produced by mechanical means, and therefore belong to Natural Philosophy. Galvanism, including electro-magnetism, is generated by chemical agency, and therefore comes under Chemistry.

In the year 1790, Galvani, a professor at Bologna, in Italy, observed that the freshly prepared legs of a frog were convulsed the moment they were brought within the influence of a powerful electric machine in action. From this experiment arose the science which, after Galvani, is called galvanism, by means of which the constitution of the crust of the earth has been determined, and the science of chemistry has been revolutionized.

79. This primitive experiment may be shown by the apparatus represented in Fig. 24. Strips of two different metals, one silver and the other zinc, are made to grasp the thigh of a grasshopper recently killed. One of the metals is curved above, and when this is brought into contact with the other metal, the leg of the grasshopper is extended, and again contracts on separating the metals.

Fig. 24.



When the same apparatus is applied to the thigh of a frog, as in Fig. 25, and the two metals are

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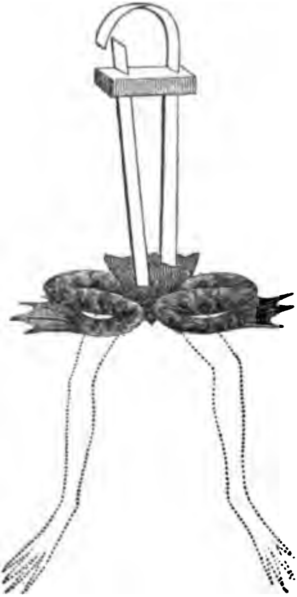
78. From what experiment did the science of galvanism commence? When was this experiment discovered?

79. Explain Fig. 24.—Fig. 25.—Fig. 26.

brought into contact, the legs of the frog are thrown out into the position represented by the dotted lines. When introduced into a tumbler of water containing a leech or small fish (Fig 26.), if the metals are brought on each side of the animal, and their contact above completed, the leech or fish is instantly disturbed, and endeavors to escape from its position in the course of the current.

Fig. 25.



80. Volta, a pupil of Galvani, first attributed these phenomena to their true cause—the contact of different metals. On this principle he arranged a series of two different metals, as represented in Fig. 27, with cloths wet with a saline or acid solution between them. In this arrangement the copper, *c*, and the zinc, *z*, alternate, and between the metals are pieces of cloth or pasteboard, and the pile commences with *z*, or zinc, and ends with *c*, or copper. On connecting the wires at the two ends, a current of electricity flows in the direction of the arrows. If the wires are separated, and one hand be placed on one end of the pile, and the other on the other end, a shock will be felt. This apparatus is called, after its inventor, the *Voltaic pile*.

Fig. 26.

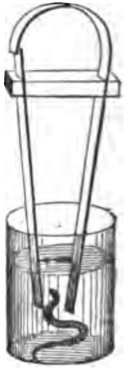
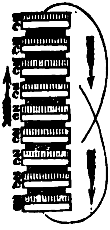


Fig. 27.



81. The discovery of Volta was announced in 1800. Since that time other forms of apparatus have superseded this pile, and yet the *principle* on which they are constructed has remained the same. This principle is, that *when two dissimilar metals are brought into contact with an acid, or sa-*

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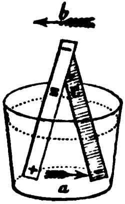
80. Who first attributed these phenomena to their true cause? Explain Fig. 27.

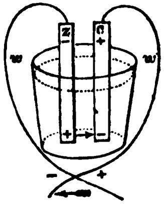
line solution, a current of electricity is produced. The simplest illustration of this principle is made by two slips of metal, *z* and *c*, (Fig. 28.) one of zinc, and the other of copper, and a glass of acid water. If *z* and *c* be placed in the solution, as long as they do not touch each other no action is excited. But if they are brought into contact at the top, then a current is established in the solution from *z* to *c*, in the direction of the arrow, *a*, and out of the solution in the direction of the arrow, *b*. The current may be considered as starting from *z*, passing to *c*, in the direction of the arrow, *a*, ascending *c* to the point where the two metals touch each other, and then descending *z* to the point from which it started. The metal, *z*, is usually *amalgamated with mercury*, which has the effect of counteracting any impurities which may be present. These impurities cause the different parts of the zinc to be dissimilar, and hence much of the galvanic action is expended between these dissimilar portions of the zinc plate, and so much is taken from the current which passes to the copper, and through the entire circuit. Amalgamation with mercury renders the surface more uniform, and thus increases the current which goes from the zinc to the copper.

Fig. 28.



82. If *z* and *c* be placed in an upright position, as in Fig. 29, then there will be no communication, and the current will not flow until they are united by two wires, as *w*, *w*, which are soldered to each of the metals *z* and *c*. When the wires touch, the communication is completed, and the electrical current begins to flow. The plate of zinc, *z*, is called the *zinc*, or *negative pole*, and the copper plate, *c*, the *copper* or *positive pole* of the battery. These terms are continually referred to in describing galvanic processes, and, therefore, should be thoroughly understood.

Fig. 29.



83. To render the effects of galvanic action more powerful and striking, *galvanic batteries* have been constructed.

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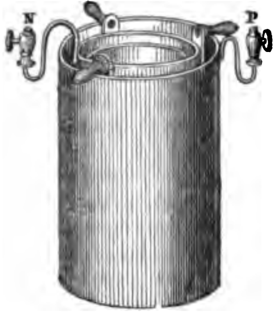
81. When was the discovery of Volta first announced? What is said of the galvanic apparatus made since that time? What is the principle of all these forms of apparatus? Explain Fig. 28. What is the effect of amalgamating zinc?

82. Explain Fig. 29. What is the zinc, or negative pole, in this figure?—copper, or positive pole?

These batteries are only a combination of plates of two different metals, on the same plan of alternation of metals, but differing from each other in form.

Fig. 30.



One of these batteries, first constructed by Dr. Hare, of Philadelphia, is called the *deflagrator*, from the energy with which it deflagrates or burns the metals and other combustible substances. This form of battery is represented in Fig. 30, where a single coil of zinc rests on the exterior cylinder of copper, by three wooden supports. The interior cylinder is also of copper. Great power is obtained in batteries of this form by multiplying the coils of copper and zinc. In a battery constructed for Yale College, there were nine hundred members, or pairs, of copper and zinc. A great variety of effects may be produced by this battery, of which one of the most interesting is the burning of charcoal points, where an arch of flame of the brightness of the sun is formed, sometimes six inches in length.

84. Among the effects of galvanic batteries, are the following:

(1.) *While the zinc of a battery in action is corroded, the copper is not acted on in the slightest degree.* This fact proves that the origin of galvanic action is *the unequal corrosion of metals by a common fluid.* The design of employing different metals in the construction of batteries, is to favor this unequal corrosion.

In whatever manner two dissimilar metals are united, this unequal corrosion will take place when they are immersed in an acid solution. Thus, if a plate of copper be fastened by any method to a plate of zinc, and both be plunged in an acid mixture, the zinc will be corroded *more rapidly* from its union with the copper, than it would have been alone, while the copper will not be acted on by the

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83. What are galvanic batteries? What is their design? What is the battery represented in Fig. 30 called? Describe this battery.

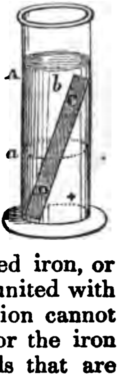
84. What is the first of the effects of galvanism mentioned? What is the origin of galvanic action? What is the design of employing different metals in the construction of batteries? What effect will be produced on a plate of zinc, if it is united with a plate of copper, and both are plunged in an acid

fluid. Iron may in this way be protected from corrosion. If a polished plate of iron be attached to a plate of zinc, and immersed in a weak solution of hydrochloric acid, the iron will remain untarnished, though if plunged alone in the dilute acid, it will be acted on immediately. On this principle is founded the method of *galvanizing iron.* Iron is covered with a coating of zinc, and as long as a particle of the zinc remains, the iron will not be acted on. Hence galvanized iron is of great use in covering objects which are exposed to the weather, and in other situations where common iron would soon be rusted.

The copper sheathing of ships might be protected in the same way; but the gradual corrosion of the copper is found necessary to prevent *barnacles*, and other animals of the sea, and sea-plants, from fastening to the bottom and sides of ships, and impeding their progress. This principle is, however, applied to the manufacture of life-boats, which are made of galvanized copper.

That galvanic action is produced by unequal corrosion, is shown by the arrangement represented in Fig. 31. A is a jar filled with nitrate of copper to *a*, and then with dilute nitric acid to *b*. C D is a slip of copper which is immersed in both solutions. The part C is dissolved by the nitric acid, but the part D being in the solution of nitrate of copper, is not acted on. This unequal action causes a current to flow from C to D, which deposits metallic copper at D, as will be explained more fully hereafter.

Fig. 31.



As tin is not as easily acted on as iron, in tinned iron, or tin plates, the iron corrodes faster because it is united with the tin; but the tin being on the outside, the action cannot take place except where it has been worn off, or the iron uncovered in some other way, as around nails that are driven through the tin, or on the edges.

85. (2.) *Ignition* may be performed in a splendid manner by a powerful galvanic battery. On connecting the ends of such a battery by fine metallic wires, these conductors become intensely heated and emit a vivid white light.

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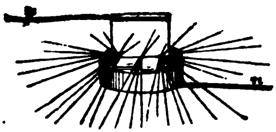
solution? How may an iron plate be protected from corrosion? In what way is galvanized iron prepared? Where is galvanized iron employed? Why is not the copper sheathing of ships protected in this way? What kind of boats are made of galvanized copper? Explain Fig. 31. What is said of the corrosion of tinned iron, or common tinned plate?

85. What is the second effect of galvanism? How is ignition by galvanism performed?

Fig. 32.



86. (3.) *Combustion.*—If the wires be sufficiently fine, or the communication be made by means of metallic leaves, the metals burn with vivid scintillations. This is represented in Fig. 32, where a piece of leaf metal (gold leaf, silver leaf, tin foil, &c.) is attached to the positive wire, *p*, and the negative wire, *n*, is connected with a metallic cover[*] which has been brightened, for the time, with mercury. When the leaf metal is brought into contact with the polished surface, it burns with a vivid light. Gold emits a vivid white light, inclining a little to blue; silver a vivid green; zinc a bluish white flame. If the galvanic current be made to pass through gunpowder, phosphorous, or a mixture of hydrogen and oxygen gases, they are inflamed. Alcohol, ether, and turpentine, may be inflamed in a similar manner, or by suddenly breaking the contact of the wire with the fluid, while the galvanic current is passing.

87. (4.) *Decompositions are produced by galvanism.* If the ends of two platinum wires, connected with the battery, are placed in water slightly acidulated to improve its conducting power, a stream of gas will be seen to rise from each. If now glass tubes, as two large test tubes of equal size, are placed over the wires where the gas is rising, they will collect this gas. One tube will be found to collect twice as much as the other, and on examining the gas in this tube it will be found inflammable, while that collected in the other tube will not be inflammable, but will *support combustion* with great energy. From these different properties of the two gases, one is known to be hydrogen, and the other oxygen; both of which will be described hereafter. The inflammable gas or hydrogen, in water, is found by this method to be twice *in volume*, the supporter of combustion, or the oxygen.

Galvanism is one of the most important agents of decomposition which the chemist possesses, and by this he is ena-

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[*] Like the tin covers which are made for glass jars.

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86. What is third effect of galvanism? How is this produced? Explain Fig. 32. What light is obtained from the combustion of gold?—silver?—zinc? What effect is produced when the galvanic current is made to pass through gunpowder, phosphorous, or a mixture of hydrogen and oxygen gases? How may alcohol, ether, and turpentine, be inflamed?

87. What is the fourth effect produced by galvanism? In what way may water be decomposed by the galvanic current? What will arise from its decomposition? Ans.—Two gases. How will these gases compare with each other in properties?—in volume?

bled to investigate the composition of a large class of bodies, with great facility.

88. In all cases of galvanic decomposition, one of the elements of the body undergoing decomposition is found at the negative pole, and the other at the positive pole of the battery. In the decomposition of water, for example, the oxygen is found at the positive pole and the hydrogen at the negative. Bodies are, therefore, classed into electro-positive, or those which go to the negative pole of the battery, and electro-negative, or those which go to the positive pole of the battery, the poles being supposed to attract bodies of opposite electricities, as in all other cases of electrical attraction.

The terms electro-positive and electro-negative are for the most part relative, for most substances are electro-positive with regard to one class of bodies, and electro-negative with regard to another class. Oxygen, however, is always electro-negative; all other bodies are, therefore, electro-positive with regard to oxygen; that is, when their compounds with oxygen are decomposed, they are found at the negative pole of the battery, while oxygen is found at the positive pole.

89. When metallic solutions are decomposed the metal is deposited on the negative pole. This is applied in the process of *electrotyping*, or the process of depositing metals by a galvanic current. This process may be illustrated by the following experiment.

With the poles of the battery, connect two polished plates of metal, as iron or copper. Suspend these in a dilute solution of sulphuric acid. If the battery is in operation it will be seen that one of the metals will be tarnished almost instantly, while the other plate remains bright. This must be owing to a different action on the two plates, for both are in the same solution; the acid acts on one and does not act on the other. The one that is acted on will be found to be always the one at the positive pole, and the plate not acted on the one at the negative pole. The action of the sulphuric acid on the plate at the positive pole, produces sulphate of copper, as will be shown hereafter. This is dissolved in the solution, and when the latter in this

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88. What are electro-positive bodies?—electro-negative bodies? Why are these terms chiefly relative? What body is always electro-negative? What are all other bodies with regard to oxygen?

89. When metallic solutions are decomposed, where is the metal deposited? What is meant by the process of electrotyping? By what experiment is this

way becomes charged, then a new operation will be observed. Metallic copper will begin to be deposited on the plate at the negative pole, the plate which hitherto had been unaltered.

By this process a solution of sulphate of copper has been formed, but it is usual to commence with making the solution by dissolving the salt itself. Then, on immersing the two poles of the battery in the solution, a deposition of metal takes place at once; at the same time, as in the former case, the metal at the positive pole is continually dissolved. The metal, therefore, at this pole is changed into sulphate of copper, and at the negative pole the sulphate of copper is changed into metallic copper, which is deposited on the metallic plate at this pole, and the sulphuric acid, *set free* from this decomposition of the sulphate of copper, *travels* over and attacks the plate at the positive pole. Thus the latter plate becomes continually smaller, while the plate at the negative pole is continually increased by fresh depositions of metal. The solution is kept charged with sulphate of copper as long as the copper plate at the positive pole remains. All other metallic depositions by galvanism are made on the same principle. If copper is to be deposited, a solution of a salt of copper is employed, and a piece of copper at the positive pole to keep up *the strength* of the solution. If silver is to be plated, a silver solution is employed, and a silver coin or other piece of silver is placed in the positive pole. To plate gold, in like manner, a solution of gold is used with a piece of gold at the positive pole.(4)

90. (5.) *Magnetism* is produced by galvanic action. Electro-magnetism has recently grown almost to a distinct science of great interest and great importance, particularly in its application to the *Electric Telegraph*. As the principle of

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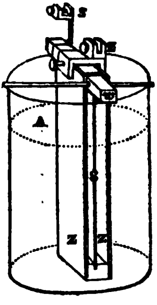
process illustrated? At which pole is the metallic plate which is acted on? What does the action of the sulphuric acid on this plate produce? What takes place when the solution becomes charged with sulphate of copper? What is the usual method of commencing the electrotype process? What then takes place on immersing the two poles of the battery? Why is the solution kept continually charged with sulphate of copper, notwithstanding this is continually decomposed and metallic copper deposited on the negative pole? Ans.—Because sulphate of copper is continually formed at the positive pole, as fast as it is decomposed at the negative pole. How is this accomplished? Ans.—The sulphuric acid which is set free by the decomposition of the sulphate of copper at the negative pole, travels over to the positive pole and there corrodes the copper wire, or plate, forming with it sulphate of copper. When silver is to be plated, what solution is used? What is placed in the positive pole? Why is a piece of silver placed in the positive pole? How is gold plated?

the telegraph and its different varieties are fully described in natural philosophy,[*] it will not be necessary to repeat that description in this work, although this instrument has relations also to chemistry. As its construction and mode of action are entirely mechanical, it is allied to natural philosophy; as the galvanic fluid by which it is put in motion, is generated by chemical agents, it might be described under chemistry.(5)

91. The *different forms* of galvanic batteries are found to produce very different results. If we take a square foot of copper and a square foot of zinc and place a wet cloth between them, we shall have a battery which cannot give shocks nor decompose water, but which will cause a fine metallic wire to become white hot, and even to fuse. If again, we take a square foot of copper and another of zinc, and cut each into 144 plates an inch square, and arrange them with similar pieces of cloth, as in the Voltaic pile, the instrument will give shocks and decompose water rapidly. From the same quantity of metal, therefore, two species of battery may be made; one consisting of a *few plates* with a *large surface*, and the other of a *great number* of small plates, or plates with *small surface*. The former produce greater magnetic and heating effects, and are called *quantity batteries;* the latter are more powerful in giving shocks, decomposing water, &c., and are called *intensity batteries*. The deflagrator, already described (83.), is an example of the first kind of battery.

Fig. 32.



92. *Smee's battery* (Fig. 32.) is an example of the second. It consists of a plate of platinized silver, or platinized[†] platinum, S, on each side of which are placed parallel plates of amalgamated zinc, Z Z. *w* is a strip of wood long enough to extend over the rim of the tumbler. To this strip of wood the zinc plates are firmly attached by means of a metal clamp. One of the poles, z, rises from

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[*] Olmsted's Natural Philosophy.

[†] Plates on which platinum is precipitated in the form of a black powder.

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90. What is the fifth effect of galvanism?

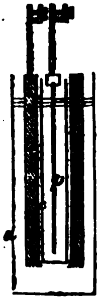
91. What is said of the different forms of galvanic batteries? What are quantity batteries? What effects do they produce? What are intensity batteries? For what effects are these batteries adapted? To which class does the deflagrator belong?

92. To which class does Smee's battery belong? Explain Fig. 32.

this clamp and is therefore connected with the zinc plates by a *metallic communication*. The other pole, S, passes through the wood and is connected with the silver. The wood serves to *insulate* the two poles from each other. These poles have screws for attaching wires.

93. *Grove's battery*, a section of which is exhibited in (Fig. 33.) is employed where great power and intensity are required. Z is the cylinder of zinc; *c* is a cup made of porous earthernware; *p* is a strip of platinum. The porous cup is filled with strong nitric acid and into this the platinum is placed. The glass cup is filled with dilute sulphuric acid and the cylinder of zinc is let down into the sulphuric acid.

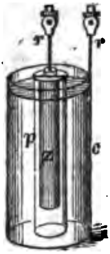
Fig. 33.



To use this battery, first fill about half full the *glass cup* or tumbler, *a*, and let down into the solution the zinc cylinder. Within the zinc cylinder let down the porous cup containing nitric acid. This will cause the sulphuric acid to rise, so as nearly to fill the tumbler. Finally, place in the nitric acid the strip of platinum, connect the poles, and the galvanic action will commence.

94. *Daniel's battery* is another common form of the galvanic battery. It consists of a copper cylinder *c*, (Fig. 34.) into which a solution of sulphate of copper is poured. Within this is a second cylinder, *p*, of porous earthernware filled with dilute sulphuric acid, into which an amalgamated zinc rod, *z*, dips. From the copper and zinc project rods, *r*, *r*, terminated in binding screws by which the polar wires may be connected.

Fig. 34.



95. Each one of these batteries has its peculiar advantages, and the object to be accomplished determines which one shall be employed. With the deflagrator, Grove's, and Daniel's, all can be accomplished that is desired; the deflagrator for magnetic purposes, Grove's for chemical decompositions, and Daniel's for gilding and electrotype purposes. If, however, only one can be purchased, the *simple form* of the deflagrator, represented in Fig. 30, will be found the most convenient.

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93. Explain Fig. 33. How is Grove's battery prepared for use?
94. Explain Fig. 34.
95. Mention the peculiar advantages of the deflagrator, Grove's, and Daniel's batteries?

LAWS OF CHEMICAL AFFINITY.

96. (1.) *Affinity takes place only between bodies of a different nature. This follows from the definition of affinity,* (see page 11.) (6)

(2.) *Bodies most opposed to each other in chemical properties, evince the greatest tendency to enter into combination.* The converse of this proposition presents this principle in a more striking light, that *bodies whose properties are most alike, manifest the least attraction.* It will be shown hereafter that many of the gases, as oxygen, chlorine, iodine, &c., are very much alike in their properties; these bodies have far less attraction for each other than they have for hydrogen and the metals, the properties of which are totally dissimilar.(7)

(3.) *As a general rule, simple bodies unite with simple, and compound bodies with compound.*

(4.) *All solid bodies which have many pores, and consequently much surface, attract fluids and gases.* A piece of charcoal the size of a walnut is intersected by many hundred partitions, which, if they could be placed by the side of each other, would cover a space a thousand times larger than the piece of coal itself covers. The force of attraction of this large surface is so powerful, that the coal can absorb from 80 to 90 times its own bulk of many kinds of gases. It is very probable that these gases, by this compression into 80 or 90 times smaller space within the coal, become fluid or solid.

(5.) *Affinity takes place only between the minute particles of bodies.* Two bodies which have a strong affinity for each other will not act on one another while in the solid mass, nor even in a state of fine powder, except in a few instances. If one of these be in solution, the action will take place readily, but it will be most vigorous when both the ingredients are in solution. Minute division, therefore, favors the action of affinity; on the other hand, cohesion opposes it.(8) In some cases it is sufficient to heat one of the solid bodies till it softens; thus iron, surrounded with charcoal and heated to whiteness, is slowly penetrated by the charcoal.

(6.) *Affinity takes place not only between two, but also between three, four, or any number of bodies.*(9)

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96. What is the first law of chemical affinity? Whence is this law derived? What is the second law of affinity? How is the converse of this proposition stated? What is the third law of affinity? Is this law universal?—Ans. There are some exceptions, but it is true in the great majority of cases. What is the fourth law of affinity? What example is given? What is the fifth law

(7.) *The compounds formed by affinity possess new properties, different from those of the constituent bodies.* Almost all substances we meet with furnish illustrations of this law, being very different in their nature and appearances from the elements of which they are composed. Water, our only safeguard against fire, contains the most inflammable of all the elements united to the greatest supporter of combustion;—to a body in which even iron and other metals burn with great energy. Our table salt is composed of corrosive and poisonous ingredients, and the same elements that form nitric acid, which will destroy the firmest parts of the body, form also, in another proportion, the atmosphere we breathe. In preparing medicines it is unsafe to infer that the compounds will possess the aggregate virtues of the simples, since by the action of affinity, the most harmless elements sometimes form compounds that are corrosive and poisonous, while others that are most corrosive and poisonous render each other inert and harmless.(10)

(8.) *Bodies have different degrees of affinity for each other.* This principle is implied by the second law already given. It is introduced under this head for further illustration, and on account of its relation to the laws which follow.

In some cases the elements of a compound body are so strongly united, that they can scarcely be separated by any means in our power; in other cases the union is so slight, that it is easily overcome, and sometimes even a spontaneous separation occurs. Between these extremes, attraction exists in many different degrees of strength. Upon this law depends the whole art of decomposing bodies; for when two bodies, A and B, are united in a compound, we have only to find a *third body*, C, which has a stronger attraction for one of them than they have for each other, and it will effect their separation, and we shall have a new compound which may be represented by A and C, B having been excluded.

The foregoing is the simplest case of decomposition. A more common mode is that called *double decomposition.* A is composed of two elements; B is also composed of two; together there are four elements, and these elements act on each other independently of their previous relations to the compounds A and B. If numbers 1 and 2 belonged to A, and numbers 3 and 4 belonged to B, then 1 of A will take

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of affinity? Mention some examples. What is the sixth law?—seventh? What examples are given? What is the eighth law? What is said the strength of affinity in some cases? How weak is it in other instances? What depends upon this law? How is this illustrated? What illustration of double decom-

3 of B and form a new substance C. And 2 of A will take 4 of B and form a new substance D. We have therefore the following formulas;—*at first* $1+2=A$; $3+4=B$: *after double decomposition*, $1+3=C$; $2+4=D$. C and D are entirely different bodies from A and B.

Double decompositions prevail where simple decompositions could not be effected. Thus, in the last example, unless the elements which we have numbered 1, 2, 3, 4, were all present, in most cases, no decomposition could be effected. It would appear that if 3 were uncombined with 4, or if it was bound by no affinity whatever to 4, that, being free, it would act with more energy in decomposing the compound $1+2$ or A, than it would in its combined state. But this is not the fact. When united to 4 it may effect the decomposition of $1+2$ when, separately, it would not have altered this compound.*(11)

(9.) *When a body, A, combines with different quantities of another, B, all the higher proportions of B are in a simple ratio to the lowest.* Thus if there are several combinations of the same bodies, A and B, and if in the first the quantity of A be just equal to that of B, then in the next higher it will be just twice, thrice, four times, &c., that of A.(12)

(10.) The most important law of Chemistry is that which is called the law of EQUIVALENT PROPORTIONS. It may be thus stated: *When a body, A, unites with other bodies, B and C, the proportion to which A unites with B and C, will represent the proportion in which they will unite with each other.* Thus, hydrogen will unite with carbon in the proportion of 1 to 6, and with oxygen in the proportion of 1 to 8. Therefore carbon and oxygen unite with each other in the proportion of 6 to 8.

(11.) The preceding law relates to simple bodies; the law

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* This may perhaps be accounted for in the following way. Upon the compound $1+2$ two attractions may be supposed to operate at the same time, viz. that of 3 for 1 to form the new compound $1+3$, or C, and that of 4 for 2, to form the new compound $2+4$, or D. Now the *sum* of these attractions acts to resolve A, or the compound $1+2$, and this evidently with greater power than either the attraction of 3 for 1, or 4 for 2 separately, and therefore a decomposition is effected by the united, which would not have been effected by the single attractions.

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position is given? How do the new compounds, C and D, compare with the first A and B? Are single or double decompositions most powerful? How is this illustrated? What is the ninth law of affinity? How is this illustrated? What is the tenth law of affinity called? State this law. How is this illustrated? What is the law of combination for compound bodies? What example is given? What is disposing affinity? What is meant by the nascent state of bodies?

for compound bodies is the following: *Add together the numbers corresponding to the elements of the compound body; the sum will represent the proportion in which the compound enters into combination.* Thus common salt is a compound of chlorine and sodium. Chlorine combines in the proportion represented by the number 35. Sodium combines in the proportion represented by the number 23. Therefore the compound of chlorine and sodium, that is common salt, combines in the proportion represented by 35+23, or by the number 58.

(12.) A peculiar chemical action is produced by certain bodies which is called *disposing affinity*, by which is meant *that affinity which exists between two or more bodies in consequence of the presence of another body.*

(13.) Affinity often takes place between bodies when first set free from their combinations by decomposition, when under other circumstances it does not occur. This state of of bodies is called the *nascent* state.[*]

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[*] Latin, *nascens*, arising.

PART II.

THE ELEMENTS AND THEIR COMBINATIONS.

97. A vast field opens before us when we leave the general principles of Chemistry, for the consideration of the chemical relations and agencies of *particular bodies.* Every object in the material world is to be explored. Without, therefore, a method of great simplicity, this immense mass of facts and details would be a labyrinth of doubt and obscurity. But here, as elsewhere, the simplicity of the laws of nature is most apparent where the greatest complexity might be expected. By a few laws of numerical exactness and simplicity, and by a few bodies which have not been decomposed, and are therefore called *elements,* all the objects in nature are formed, and combinations produced without number.

98. The elements, or simple undecomposed bodies, are 61* in number, and are divided into metals and non-metallic substances. The relations of the non-metallic substances are more extensive than those of the metals; we shall therefore consider these first. The following is a list of these substances.

Oxygen,
Nitrogen,
Hydrogen,
Carbon,
} *Organogens.* (Components of organic forms.)

These four elements make up, almost exclusively, organized objects, both animal and vegetable.

Sulphur,
Selenium,
Phosphorus,
} *Pyrogens.* (Fire producers.)

These elements are distinguished by their easy combustibility.

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[*] Perhaps 63, including norium and ilmenium.

97. What portion of the subject of chemistry do we now leave? Upon what division of the subject do we enter? What is said of the extent of this subject? How is the simplicity of the laws of nature illustrated in this part of chemistry?

98. What are elements? How many elements are there? Into what two

$$\left.\begin{array}{l}\text{Chlorine,}\\ \text{Iodine,}\\ \text{Bromine,}\\ \text{Fluorine,}\end{array}\right\}\textit{Halogens.}\quad\text{(Salt producers.)}$$

These elements, by their combinations with the metals, produce saline compounds, as common salt formed of chlorine and the metal sodium.

$$\left.\begin{array}{l}\text{Boron,}\\ \text{Silicon,}\end{array}\right\}\textit{Hyalogens.}\quad\text{(Glass producers.)}$$

These elements, united with many bases, form the various kinds of glass.

The relations by which these bodies are arranged under the four classes given above, are those by which they are best distinguished from each other, although some of these bodies have other relations of equal or greater importance than those upon which these distinctions are founded. This is especially true in the case of the three first elements. Of these, oxygen and nitrogen form the atmosphere, and will be considered under that head; oxygen and hydrogen form water, and will be described under that subject.

THE ATMOSPHERE.

99. Two transparent fluids form the atmosphere,—oxygen and nitrogen. They are called gases; that is, they are *permanently elastic aeriform fluids.* Many other bodies are elastic, but gases alone are permanently elastic, for they alone return to their original volume when the compressing force is removed, however great that force may be, or however long continued.

OXYGEN.

100. The first and most important of all gases, is oxygen. It is never found in a separate state, but is combined with several substances, from which it is obtained by the appli-

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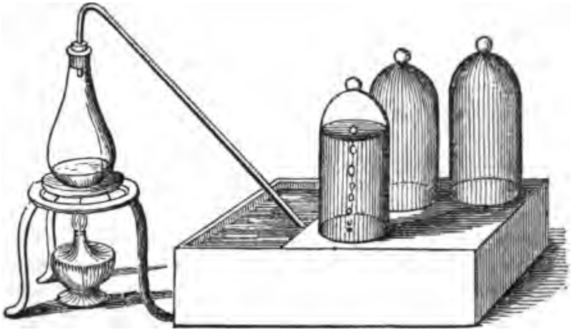
classes are they divided? Mention the organogens. What is meant by this term? Why is this term applied to these four bodies? Name the pyrogens? What is meant by this term? Why is it applied to sulphur, selenium, and phosphorus? Name the halogens. What is meant by the term halogen. Why is it applied to chlorine, iodine, bromine, and fluorine? Name the hyalogens, and define the term. Why is this term applied to boron and silicon?

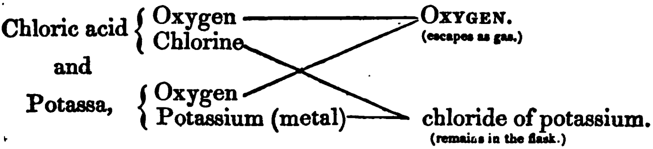
99. What two transparent fluids compose the atmosphere? Why are they called gases?

cation of heat. The most convenient of these substances is *chlorate of potash.* The process is represented in Fig. 35. A glass flask is fitted with a bent tube passing through a cork. This tube conveys the gas beneath the mouth of an inverted jar.(13) An ounce* of chlorate of potash, and 48 grs. ($\frac{1}{10}$ part) of black oxide of manganese, are well mixed and put into the flask. The heat from the lamp beneath soon drives off the gas and displaces the water from the jars, until, from a small quantity of the salt, quite a number of jars are filled with oxygen very nearly pure. A thin metallic cup is placed beneath the flask to protect it from fusion; but this should be quite small, otherwise it will conduct off too much heat. A little sand is usually placed in this cup.(14)

Fig. 35.



Chlorate of potassa consists of



101. *Properties.* Oxygen is colorless, and has neither taste nor smell. It is heavier than air in the proportion of 11 to 10. It unites with all the simple substances, or ele-

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* A larger quantity, as five ounces, is more convenient after some familiarity with the process has been acquired.

100. What is the most important of all the gases? Is it ever found in a separate state? How is it obtained? What is the most convenient source of oxygen? Explain Fig. 35.

ments,* and with a vast number of compound bodies. It therefore constitutes a large portion of the earth. Water contains 89 per cent. and atmospheric air 23 of its weight of oxygen. Common water will not perceptibly dissolve oxygen, because it already holds a quantity in solution; but if the water is previously boiled, and then allowed to cool in a close vessel, it dissolves 3½ per cent. of oxygen.

102. Oxygen is that constituent of air which *supports animal life*, and yet in a pure state it is deleterious to life. If an animal, as a mouse, be placed in a jar of oxygen, he will live four times as long as he will live in a jar of equal capacity containing common air. This is not because oxygen is a better supporter of life than common air, but because the oxygen of the jar of air is sooner exhausted than that of the other which contains pure oxygen. If the first jar were supplied with continual portions of fresh air, the animal would live; but in the second jar, with fresh portions of oxygen, it will die in a few hours. This gas is too exhilarating, and needs to be diluted, as with nitrogen in common air.

103. It is sometimes used to resuscitate life. Men and animals have been resuscitated by oxygen, when all other means of restoring life have failed.

104. Oxygen is that constituent of air which enables it to *support combustion*. This is proved by the fact that the products of the combustion of all bodies weigh more than the bodies from which they were obtained, and this increase of weight is exactly that which has disappeared during the process. Combustion, however, does not usually take place by mere *contact* of oxygen; heat, light, electricity, compression, expansion, contact with platinum or certain other metals, or with a body already in the process of oxidation, must be employed, according to circumstances, to produce this combustion. When once commenced, the action goes on usually with great energy, being supported by the heat generated by the combustion itself. The temperature required to produce the combination of any substance with oxygen, is different, not only for different substances, but

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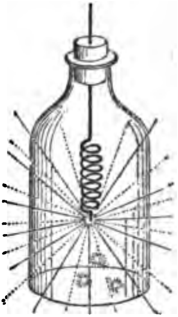
* Except fluorine.

101. Mention some of the properties of oxygen.
102. What is said of the relations of oxygen to animal life?
103. For what purpose has oxygen sometimes been employed?
104. What is said of the relations of oxygen to combustion? What must be employed to commence the combustion of a body in oxygen? In what way does combustion continue itself? What is meant by slow combustion?—rapid

even for the same substance,—in the latter case producing two distinct kinds of combustion, one called the *slow combustion,* as that of phosphorus at ordinary temperatures, and the other the *rapid combustion,* as that of phosphorus when ignited. Charcoal also burns slowly below a red heat. Slow combustion often passes into rapid combustion, as when phosphorus is dried on a piece of filter paper and placed on dry cotton. Fires in ships and manufactories have sometimes originated in this way, from the slow combustion of cotton or tow moistened with oil. Charcoal, when heaped in masses, often takes fire in this way, and the explosion of powder mills has been produced from this cause.

105. The energy with which pure oxygen can support combustion, may be illustrated by a variety of pleasing experiments. Fig. 36 represents the method of burning iron in oxygen gas. A wire is terminated by a match of sulphur and thread. This is lighted and allowed to burn for a short time, until it becomes heated, and then, while a little fire yet remains on the iron, the stopper is carefully removed, and the wire let down into the jar. Instantly a blue flame is seen, which is that of the sulphur. As soon as this is burnt off, the iron takes fire, and burns with the most splendid scintillations. Globules of iron will be thrown off, which, if collected and weighed, will be found to weigh more than the iron which was consumed, on account of the oxygen which has combined with them. If the experiment is made in a jar, standing on a plate, the fused globules melt into the plate, after falling through a stratum of water half an inch thick.(15)

Fig. 36.



106. *Oxides and acids.* All the compounds of oxygen are either oxides or acids. Acids are characterized by peculiar properties, which will be described more fully hereafter. They are generally known from their sour taste and their reddening vegetable blue infusions. Oxides are those compounds of oxygen which are not acids. Thus water, in chemical language, is an oxide of hydrogen, because it is composed of oxygen and hydrogen (87.), and does not pos-

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combustion? Mention some examples of slow combustion passing into rapid combustion?

105. Explain Fig. 36.

106. Into what two classes are the compounds of oxygen divided? How are

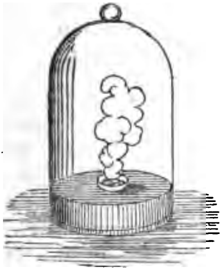
sess acid properties. The oxides are also subdivided according to the proportion of oxygen which they contain. *Protoxide* is that oxide which contains one equivalent of oxygen and one of the base with which it is combined. In some cases a smaller proportion of oxygen combines with the base. These compounds are called suboxides, by which is meant those oxides which have less oxygen than that which is called the *prot* or *first* oxide. *Deutoxide* contains twice as much oxygen as the protoxide. *Sesquioxide* (Latin *sesqui*, one and a half) is *halfway* between protoxide and deutoxide. *Tritoxide* is the third oxide, containing three times as much oxygen as the protoxide. *Peroxide* (Latin *per*, which denotes completeness) is the *highest oxide*, whether that be the second if there are only two, the third if there are only three, or the fourth if there are only four. This is also usually applied to the highest compound of oxygen which does not possess *strongly marked* acid properties.

107. While the oxides are thus distinguished by prefixes, the acids are distinguished by affixes or additions. The two terminations, *ic* and *ous*, are used to distinguish acids, *ous* denoting the smaller proportion and *ic* the larger. Thus nitric acid contains a greater proportion of oxygen than nitrous acid, and sulphuric acid than sulphurous acid.(16)

NITROGEN.

108. If we withdraw the oxygen from a given portion of common air, the residue is nitrogen. A piece of phosphorus about the size of a small pea is placed upon a little saucer of tin or iron, and this upon a float of cork or wood. It is then set on fire and instantly a jar is inverted over the burning phosphorus (Fig. 37.) (17). The phosphorus will consume the oxygen of the air beneath the bell glass, and the water will rise. By the combustion of the phosphorus, phosphoric acid is formed, which is absorbed by the water in the jar, and nothing remains but nitrogen.

Fig. 37.



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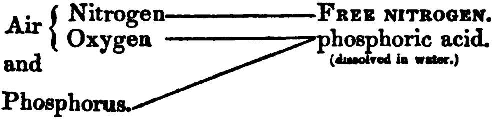
acids generally known? What compounds of oxygen are called oxides? What is water called in chemical language? What is meant by the term protoxide? —suboxide?—deutoxide?—sesquioxide?—peroxide?

107. In what manner are acids distinguished? What does the termination, ous, denote?—ic? What examples are mentioned?

108. Explain Fig. 37.

The jar contained



109. Nitrogen is found in a free state in the air bladders of fish, and in other cavities in the bodies of animals and vegetables. Its properties are chiefly negative. It does not support combustion (18), or animal life. A mouse placed in a jar of nitrogen dies almost instantly. It is not poisonous, however, like some gases, but it destroys life by suffocation. It has probably the greatest affinity for heat of all ponderable bodies, and by this strong affinity for heat its compounds are easily decomposed. The nitrogen is disengaged in the gaseous form, often with such violence as to produce explosion.

110. Nitrogen is very widely diffused in nature, particularly in the organic kingdom, for we find it in all plants and animals. It is an essential constituent of the animal frame.(19) It is, therefore, abundantly contained in the food of all animals. The following table contains the proportion of nitrogen in some of the most common articles of food.

Rice,	81.	Eggs, (yolk,)	305.
Potatoes,	84.	" (white,)	345.
Turnips,	106.	Ham, (raw,)	539.
Rye,	106.	" (boiled,)	807.
White bread,	100 to 125.	Mutton, (raw,)	773.
Milk,	237.	" (boiled,)	852.
Peas,	239.	Beef, (raw,)	880.
Beans,	320.	" (boiled,)	942.

111. Nitrogen is somewhat lighter than common air, and, of course, lighter than oxygen. Still it is diffused throughout the atmosphere in every part, although not chemically combined with oxygen. This principle of the *diffusion of gases*, may be illustrated by the following experiment:—Two flasks, (Fig. 38.), are connected by a tube passing through their corks. One of the flasks con-

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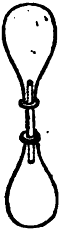
109. Where is nitrogen found in a free state? What is said of its properties? What is its effect on combustion and animal life? In what manner does it destroy life? What is said of its affinity for heat? What is said of the compounds of nitrogen?

110. Why is nitrogen an essential constituent of food?

111. How does the density of nitrogen compare with that of common air?

Fig. 38.



tains oxygen, and the other nitrogen. When placed as represented in the figure, the heavier gas, or oxygen in the lower flask, and the lighter or nitrogen in the upper, after remaining a day or two, the gases in both will be found alike, or, rather, each flask will be found to contain a mixture of oxygen and nitrogen. In this case, the nitrogen, though the lighter gas, has descended from the upper flask through the tube into the lower, and the oxygen has ascended through the tube into the upper flask. This property, which gases possess of mingling with each other, notwithstanding their difference of specific gravity, is called the *diffusion of gases*. It is a principle of the first importance, and will therefore be explained more fully hereafter, when the different gases are known. It is owing to this principle, that the gases which make up the atmosphere, are found in every part of the earth, both on the highest mountains and in the deepest mines. Besides pure air, which is composed of oxygen and nitrogen, in every part of the atmosphere two other gases, carbonic acid and ammonia, with watery vapor, are found as leading constituents.

112. *The atmosphere* surrounds our globe to the height of about forty miles, and far beyond this height it has been proved to exist in a state of extreme rarity. It is the breath of life to animals, for no other gas, or combination of gases, is adapted to this purpose; it is equally necessary to plants which absorb it, and the gases of which it is the vehicle. By respiration, it acts upon the blood of animals, renewing perpetually its vital properties, and through the leaves of plants it perfects the sap and renders it suitable for their nourishment. No animal, however low in the system of creation, has been found without the means of introducing air freely into every part of its system.

WATER.

113. Water, when analyzed, has been found to consist of two volumes of hydrogen to one of oxygen, and eight of oxygen to one of hydrogen, by weight. The method of analysis by galvanism has been described (87). The following is another method:

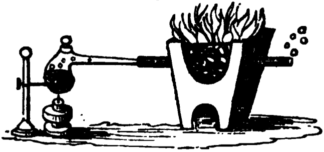
Explain Fig. 38. What is meant by the diffusion of gases? What is the effect of this principle upon the gases of the atmosphere?

112. How far above the earth does the atmosphere extend? What is said of its importance to animals and plants?

113. What is the composition of water? Explain Fig. 39. What may be

A gun-barrel, (Fig. 39.), is made to pass through a furnace. It is connected at one end with a retort holding some water. When the gun-barrel has become red hot in the furnace, heat is applied beneath the retort by a lamp, and the vapor comes through the gun-barrel, where it is decomposed by the ignited surface. The oxygen unites with the red hot iron, and the hydrogen issues from the end of the gun-barrel.

Fig. 39.

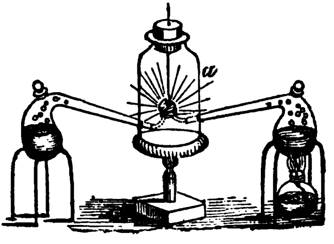


A porcelain tube may be used instead of the gun-barrel, if it is loosely filled with iron turnings, which, when red hot, absorb the oxygen, and *their increase in weight will show the amount of oxygen absorbed.* If the experiment be accurately performed, it will be found that eight times as much oxygen, by weight, has been obtained, as hydrogen.(20)

114. *At a very high temperature,* water is decomposed, as is seen when a small portion of water is thrown on an intensely hot fire. Water thrown on a large quantity of burning tar increases its combustion, and the same effect is produced in large fires, where water thrown from engines increases the rapidity and energy of the fire. If a ball of platinum of the size of a large pea, with a wire attached to it, be heated to bright whiteness till it begins to show signs of fusion, and then plunged into hot water, minute bubbles of gas rise with the steam, which consist of a *mixture* of oxygen and hydrogen.

115. *The synthesis* (4.) of water may also be performed in the following manner. Put into one of the retorts in Fig. 40, some chlorate of potash, and apply heat beneath; into the other put the ingredients for making hydrogen gas (116.) Tie some platinum sponge to a wire of the same metal, several times coiled around it; heat this red hot, and immerse it in

Fig. 40.



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used instead of the gun barrel in this experiment? In this case how will the amount of oxygen absorbed be determined? How much more oxygen than hydrogen, by weight, does water contain?

114. What facts show that water is decomposed at a very high temperature?

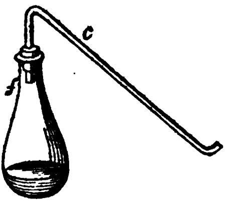
the mixed gases in the jar, *a*, so that the hydrogen shall blow upon one side, and the oxygen upon the other side; an explosion will ensue, after which the gases will burn more quietly. The platinum sponge will glow with the intensity of the heat, and, by the union of the gases, water will be formed, and will be deposited on the inner surface of the jar, *a*.(21)

The same effect may be produced by burning a jet of hydrogen gas in a tall glass tube. Water will be formed on the inside of the tube, by the union of hydrogen and the oxygen of the air. Water is therefore composed of oxygen and hydrogen, as is determined by both analysis and synthesis.

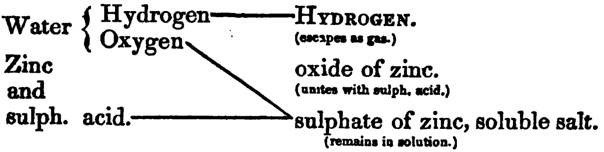
HYDROGEN.

116. Hydrogen is never found in a free state. For the purposes of experiment it is always obtained by deoxidizing water. Thus, in passing the vapor of water through a red hot iron tube, the red hot surface absorbs the oxygen, and the hydrogen issues from the end of the tube. A more common method of obtaining hydrogen is represented in Fig. 41. The flask, *f*, is provided with a bent tube, *c*, which descends through the cork into the flask. The cork is first taken out, and a few small pieces of zinc are placed in the flask. Upon these, diluted sulphuric acid is poured. The flask is now closed with the cork, and the gas comes over at the end of the bent tube.(22)

Fig. 41.



The flask contains


Water { Hydrogen —— HYDROGEN. (escapes as gas.)
Oxygen
Zinc
and
sulph. acid. —— oxide of zinc. (unites with sulph. acid.)
sulphate of zinc, soluble salt. (remains in solution.)

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115. Explain Fig. 40. In what other way may the synthesis of water be performed?

116. Is hydrogen ever found in a free state? How is it always obtained for the purposes of experiment? Explain Fig. 41. In forming hydrogen by this method, between what two substances is the direct action? How does zinc form hydrogen from water? Why is the presence of some acid necessary? What is meant by disposing affinity? Does sulphuric acid facilitate the formation of hydrogen by increasing the affinity of the zinc for the oxygen of the

From the diagram it is evident that the *direct action* in forming hydrogen is between the water and the zinc, the latter drawing away the oxygen from the water, and leaving the hydrogen free. But without the presence of sulphuric, or *some other* acid, the zinc almost instantly becomes coated with the oxide of zinc, and this coating, being insoluble in water, prevents all further action until the acid is added, which dissolves it, and thus leaves a bright surface of zinc to the renewed action of the water.

But besides this agency of sulphuric acid, its *presence* also facilitates the process by *disposing affinity* (p. 64), for if acid be not present, a piece of zinc, however bright, or even when heated, will not become oxidized, or, in other words, will not produce the decomposition of water by withdrawing its oxygen, until after a long time, and but to a very small extent. That the hydrogen is not derived from the sulphuric acid, may be proved experimentally, by adding concentrated acid to zinc, when no action will take place, but this will commence when water is added. A large quantity of water will be required to produce the greatest action.(23)

117. Hydrogen is a colorless gas; as ordinarily obtained it has a smell slightly fetid, but when passed through lime water, and afterwards through alcohol, it becomes pure, and then has no smell. Like nitrogen, it is hostile to life, but is not poisonous, and takes away life by suffocation.

It is the lightest of all known forms of matter. When inhaled, as it may be without injury if pure,* it gives to the voice a peculiar shrillness.(24) It produces, after two inhalations, disagreeable sensations, with a loss of muscular power. It combines with a large number of substances, and many of its compounds are of great importance. It is sometimes employed in inflating balloons. Soap bubbles, inflated with hydrogen gas, ascend like balloons. To inflate the soap bubbles, a bladder, furnished with a pipe and stopcock, is employed. The pipe being dipped in a solution of soap, a gentle pressure is given to the bladder, when the bubbles will be formed, and finally rise from the pipe rapidly to the ceiling.(25) Musical tones are produced when a

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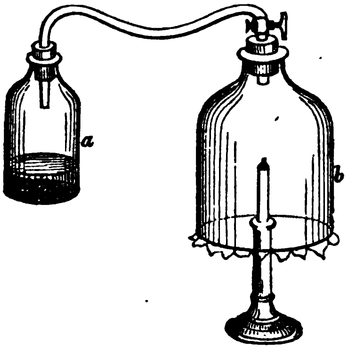
* It is generally sufficiently pure for this purpose.

water? By what experiment may it be proved that the hydrogen is not derived directly from the acid?

117. Mention some of the properties of hydrogen. What effect does it produce on the voice when inhaled? What is said of its power of combination,

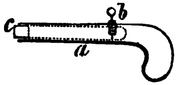
small jet of this gas is burned in a glass or other tube. These tones are also produced by several other gases. They are probably caused by a series of explosions, which succeed each other rapidly, as the flame nearly goes out, and relights in the tube.(26) Though highly inflammable, hydrogen is not a supporter of combustion. Its inflammability, and, at the same time, the fact that it extinguishes the combustion of bodies introduced within it, may be shown by the following arrangement. A bottle, *a*, (Fig. 42.) is provided with an india-rubber tube, which conveys the gas to a bell-glass, *b*. This bell-glass is held in the hand, and the hydrogen allowed to drive out the air, which it does by its greater lightness, filling the bell-glass gradually, from top to bottom. The hydrogen is now set on fire by a candle at a bottom of the jar, which *goes out itself as it enters the gas within the bell-glass, but is relighted at the mouth as it is drawn out again.*(27)

Fig. 42.



118. Hydrogen explodes when mingled with the common air, and more violently when mixed with oxygen gas. The mixture may be made in a strong brass cylinder, or pistol *a*, (Fig. 43.) A cork is inserted at *c*, and the finger held over the small orifice *b*. On removing the finger, and instantly applying a match, the mixed gases explode and drive out the cork. The gases are mixed in the proportions of two volumes of hydrogen to one of oxygen, or in those proportions in which they unite to form water.

Fig. 43.



119. The most intense heat, except, perhaps, that produced by galvanism, is made by burning hydrogen with

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and the importance of its compounds? For what is it sometimes employed? In what manner may soap bubbles be inflated with hydrogen? How are musical tones obtained from a jet of hydrogen? Explain Fig. 42.

118. Explain Fig. 43?

119. For what purposes is the mixture of oxygen and hydrogen gases employed?

oxygen. By this method, the *Drummond light*, and the flame of the *compound blowpipe** are produced. The latter causes the most intense heat which the chemist can command, and in a space not greater than that occupied by the flame of a candle.

120. *Water is a chemical combination; air is a mechanical mixture.* In air, therefore, the peculiar properties of each component, oxygen and nitrogen, are to a certain extent preserved. But in water, the peculiar properties of both oxygen and hydrogen are entirely lost. Oxygen is the greatest of all supporters of combustion, and hydrogen the most inflammable body; but water is used for extinguishing fire, and, therefore, is neither inflammable nor a supporter of combustion. Oxygen is exciting and stimulating to the vital processes; watery vapor, if inhaled, would produce death by suffocation.

121. Some of the leading properties of *water* are the following. When pure, it is a transparent, colorless liquid, which has neither taste nor smell. It boils at 212°, although the temperature of the boiling point, depends on the degree of pressure upon its surface. Under a vast pressure, it has been found to undergo a slight diminution of volume, amounting to $\frac{1}{20,000}$ part, for a pressure equal to that of the atmosphere, or 15 pounds to the square inch. It cannot be found pure in nature, but the purest water is obtained by melting freshly fallen snow, or by receiving rain in open vessels, at a distance from houses. Even this water is not absolutely pure, for, if placed under the exhausted receiver of an air pump, bubbles of gas escape from it, and this gas is found to contain much more oxygen than common air. It also contains more or less of ammonia, which it absorbs from the atmosphere. All common water, sinking through the earth, and running beneath the surface, becomes charged with earthy and saline matters; hence, to obtain pure water, it is necessary for the chemist to distil this water. The *solvent powers* of pure water are, in some cases, greater than those of common water.

* These will be described hereafter.

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120. What is said of the nature of the combination of the elements of water as compared with those of air? In what respects do the properties of water differ from those of its components? Why does air possess many of the properties of its components? Ans. Because it is a mechanical mixture and not a chemical combination.

121. Mention some of the leading properties of water. What is the effect of a vast pressure upon water? Is water found pure in nature? How is the purest water obtained? Is water thus obtained absolutely pure? What is said

The chemical properties of water are of the greatest importance. Its solvent powers far exceed those of any other body. It absorbs gaseous bodies, and holds in solution solid substances, acids(28), alkalies, and salts, while it does not alter their properties, or is *neutral* to all these bodies. These solvent powers are, generally, increased by heat; but in a few cases, as in the case of common salt, *cold* water holds as much in solution as warm water, and in a few instances also, its solvent powers are greater than those of warm water.(29)

122. The purposes which water serves are numberless, and of vast importance. All the tribes of the vegetable, as well as those of the animal kingdom, are nourished by water. Though perfectly inodorous in itself, watery vapor is the medium of the sweetest perfumes, and there is no bloom or beauty in nature, without the presence of water. Even the sky has a deeper blue when the atmosphere is fully charged with moisture, and sun-light and star-light are much more intense before and after a shower of rain. In southern latitudes, where a warmer climate produces a greater amount of watery vapor, the beauty of the sky by night, and the brilliancy with which the sun shines by day, are unknown in more northern countries.

The health of large and populous cities is dependent on an abundant supply of water; as a detergent, as an absorbent of the most deleterious gases, as a powerful mechanical agent in the waterfall and in the form of steam, water is applied to a great variety of purposes. It is the most indispensable beverage to man, and to all animals that inhabit the earth; it is a solvent of a great variety of bodies, and a constituent part of many; it is a medium of chemical action, and its presence is necessary in a great variety of cases. The crystallization of bodies rarely takes place without the presence of water, so that this is the source of the beauty of inorganic nature, as well as that of the organized world.(30) Its own crystals, in the form of snow, are greater in variety, and more beautiful in form, than those of any other substance. Neither earth nor air is so populous with life as water, from the animals that

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of common water? How do the solvent powers of pure water compare with those of common water? What is said of the chemical properties of water? What is the effect of an increase of temperature on its solvent powers?

122. What are some of the purposes served by water? What effect has the presence of moisture upon the color of the sky, and upon the light of the sun and the stars? What is said of the appearance of the sky in southern latitudes? What other purposes are served by water? What relation has water to the crystallization of bodies? How do the crystals of snow compare with those

swarm in the pool or spring, to those that fill the waters of the ocean.

We cannot, therefore, too much admire a substance so beautiful in itself, so bountifully provided, and so wonderfully adapted to the wants of man. "Wherever a spring rises or a river flows, there should we build altars and offer sacrifices."*

CARBON.

123. This is the last of the organogens, or those elements which prevail throughout the animal and vegetable kingdoms. Carbon is also largely diffused in the mineral kingdom. Its most striking peculiarity is the different conditions under which it occurs. Among these are,

(1.) *The diamond,* which is nearly pure carbon. It was probably fused at a high temperature, and crystallized by slow cooling, from this state of fusion. The figures beneath represent some of the forms of the diamond. Of these, Fig. 44. is a *cube,* Fig. 45. a *regular octahedron,* Fig. 46. a *rhombic dodeca-hedron,* and Fig. 47. an octahedron with its faces rounded, or curved; diamonds occur of this form, sometimes almost spherical. The diamond is nearly infusible, but when exposed to the flame of a condensed mixture of gases, or the heat produced by a powerful galvanic battery, it is fused. If heated without contact of air, it is not altered, even by a very intense heat, but when heated to ordinary redness in a vessel of oxygen, it burns with facility, yielding carbonic acid gas. It is the hardest substance known. It is cleaved or split without difficulty, in particular directions, but can only be cut or abraded by the fragments or

Fig. 44.

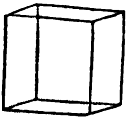


Fig. 45.

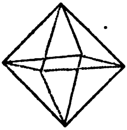


Fig. 46.

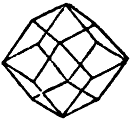
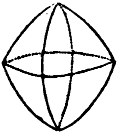


Fig. 47.



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* Seneca.

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of other substances? How does water compare with the earth or the atmosphere, as a medium of life?

123. What are some of the sources of carbon? What are some of the forms under which it is found? What is said of the diamond? What are some of the crystalline forms under which the diamond is found? What other properties of the diamond are mentioned? Mention some of the properties of plum-

powder of the diamond itself. A very useful application of the diamond is made by the glazier, in cutting glass. A diamond having the rounded octahedral figure, held with its edge on the surface of glass, and drawn along with a gentle pressure, causes a split or cut which penetrates to a considerable depth into the glass, and determines its fracture with perfect certainty.(31)

(2.) Carbon also occurs in the various forms of *charcoal, anthracite coal, coke*, &c.

(3.) *Plumbago.* This substance has the metallic lustre, is opaque, and so soft and unctuous that it is used to diminish the friction of machinery. Crystals of plumbago or graphite are not common, but when they occur they have the figure of a short six-sided prism,—a form which has no geometrical relation to that of the diamond. This mineral is used in lead pencils; it is somewhat rare. The finest and most valuable is brought from Borrowdale, in the northwestern part of England. It is found there in an irregular vein, traversing the slate beds.

(4.) *Lampblack* is a powerful absorbent of light and heat, and possesses a very strong affinity for oxygen, sometimes taking fire spontaneously in the air.

These substances, although so entirely different from each other, are all composed of nearly pure carbon. They form examples of what is called the *allotropism* of bodies. By this term is meant, that the same body exists in states or conditions which differ entirely from each other in their appearance and properties. Substances could hardly be found differing from each other more than the diamond and charcoal, or lampblack, plumbago, &c.; yet these substances are all carbon, very nearly pure. In the diamond, carbon is transparent and a non-conductor of electricity; but in plumbago and charcoal it is opaque, possessed of metallic lustre, and a good conductor of electricity; and in these forms, therefore, it differs not only from the diamond, but from the other non-metallic elements, which, like the diamond, are non-conductors of electricity, and generally transparent. The diamond is the purest form of carbon; charcoal the next, plumbago generally contains a little iron, although this is sometimes no more than a trace. Lampblack is very nearly pure carbon.

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bago. Is there any connection between the crystals of plumbago and the crystalline forms of the diamond? Whence is the finest plumbago obtained? Mention some of the properties of lampblack. What is meant by the allotropism of bodies? What is the purest form of carbon? What does plumbago usually contain?

124. Charcoal may be formed, for the purposes of experiment, by plunging small pieces of wood beneath melted lead or tin, or beneath sand heated to redness in a crucible. By this process the volatile parts of the wood will be driven off, and the carbon or charcoal remain behind.(32)

In preparing charcoal on a large scale, piles of wood are erected, which are covered with turf and moistened earth, and the wood is then kindled. This would be extinguished, however, for want of air, if holes were not made in different parts of the kiln, through which fresh air is admitted, and the burnt air escapes. Only so much should be admitted as is necessary for expelling the volatile parts of the wood. When this has been accomplished near the holes, they must be closed, and new ones made at other points. At last all the openings are carefully stopped, that the fire may be put out. When cold, the wood will be found thoroughly charred, the shape of the knots and the rings being still perceptible. All the vessels of the wood are so perfectly preserved, that when a section of the charcoal is magnified many hundred times by the solar microscope, the structure of the wood from which it is formed is still visible. One pound of wood yields about a quarter of a pound of charcoal.

Charcoal for the manufacture of gunpowder, is prepared in cast-iron cylinders. The cylinders are placed across a furnace, and there is a small vent left for the escape of the volatile parts of the wood, but not sufficient for free access of air. Alder, dogwood, and willow, are the kinds of wood preferred in making charcoal for gunpowder.

Charcoal is unchanged by heat, when not exposed to the air. After intense ignition, it becomes hard enough to scratch glass and wear a file. After being ignited, it absorbs the gases without alteration, and heat is developed during the process. The snapping of coal when placed in the fire, is owing to the sudden expansion of the gases and vapors confined within its pores. If a piece of recently ignited charcoal be placed under a jar which stands over mercury, it will absorb many times its volume of air, as will be shewn by the rise of the mercury within the jar.

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124. How may charcoal be formed for the purposes of experiment? Describe the process of preparing charcoal on a large scale. How much charcoal can be made from a pound of wood? How is charcoal prepared for the manufacture of gun powder? What kinds of wood are selected for this purpose?

125. Mention some of the properties of charcoal. To what is the snapping of coal when placed on the fire owing? How may the power of recently ignited charcoal to absorb air be shown by experiment?

126. Charcoal is unaltered by air or moisture. The figures on the dial plates of steeples, which are painted black, often stand out in bold relief, while the rest of the wood, painted white, is worn away. This preserving power of black paint is owing to the fact that charcoal forms its basis. The beams of the theatre at Herculaneum were converted into charcoal by the lava which overflowed that city, and for seventeen hundred years they have remained entire, and still present the appearance of recently formed charcoal.(33)

127. Charcoal has the power of absorbing the bad odors and coloring principles of most animal and vegetable substances. Tainted meat is made sweet by burying it in powdered charcoal, and foul water is purified by being strained through it.(34) The sirup of the sugar-cane is rendered colorless by being passed through sacks of animal charcoal (bone-black), prepared by igniting bones.(35) After being used for sometime, this charcoal loses its decolorizing power, but regains it on being heated to redness.

Charcoal is of great service in reducing metals from their oxides. This it does by its great affinity for oxygen, which causes it to take the oxygen from the oxide and reduce the metal.(36)

SYMBOLS.

128. The composition of bodies is most conveniently expressed by *symbols* of the elements of which they are composed. For this purpose, every elementary substance is designated by the first letter of the *Latin* name in capitals; or, where several names begin alike, by this and the most *characteristic* small letter in the word. The following table contains the symbols and *combining numbers* of the organogens. The meaning of the term, *combining number*, is somewhat complex, and requires full illustration to be understood. It will, therefore, be explained more fully hereafter, when many of the combinations of the gases being known, they may be employed in illustration.

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126. What are the relations of charcoal to air and moisture? Mention some examples.

127. What is said of the absorbent properties of charcoal? How is charcoal that has lost its decolorizing power restored? In what way does charcoal reduce metals from their oxides?

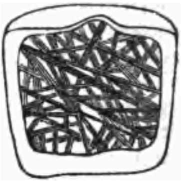
128. In what manner is the composition of bodies most conveniently expressed? Whence are these symbols obtained? Write the symbols and the combining numbers of the organogens.

	Symbol.	*Combining Number.*
Oxygen,	O.	8.
Nitrogen,	N.	14.
Hydrogen,	H.	1.
Carbon,	C.	6.

SULPHUR.

129. Sulphur is exhaled in large quantities from volcanoes, either in a pure state, or in combination with hydrogen; by condensing in fissures, it forms sulphur veins, from which the greater part of the sulphur of commerce is derived. It exists also in combination with many metals(37), as iron, lead, copper, zinc, &c., in rocks and mineral waters.(38) Some plants also contain sulphur, and it is found in all animal substances. It is a pale, greenish yellow, solid, without smell, unless when warm or rubbed, when it gives off a smell unlike that of any other body, and therefore called the smell of sulphur. It is very friable, a roll of it emits a crackling sound, and sometimes breaks when held in the warm hand. It melts readily at a heat of only a few degrees above that of boiling water, forming a transparent and nearly colorless liquid. As the temperature is elevated, the liquid becomes orange-yellow and thick, and at 482° passes abruptly into a dark brown. At about 600° it sublimes, and the condensed product is called the *flowers of sulphur*.(39) If heated for a time at this temperature, and then suddenly poured into cold water at a low temperature, it becomes, on cooling, elastic like india-rubber, and may be drawn out into long threads. By keeping for a few days, it slowly returns to its usual condition.

Fig. 48.



130. Sulphur crystallizes in a very beautiful manner. Fig. 48 is a section of a crucible, showing the form of this crystallization. A large crucible is filled with sulphur, placed in a furnace, and the sulphur allowed to melt very gradually. When all the sulphur is melted, it is removed from the furnace and placed on moist sand. The top is also covered up, that the sul-

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129. What is the chief source of sulphur ? In what other forms does it also exist ? What are some of its properties ? At what temperature does it melt ? What does it form in melting ? What is the effect of an elevation of temperature upon this liquid ? At what temperature does sulphur sublime ? What is the condensed product called ? If suddenly thrown into cold water at this temperature what effect is produced ? Is the elastic substance thus formed permanent ?

130. Explain Fig. 48.

phur beneath may cool as fast as that on the surface. After a solid crust is formed on the surface, this is pierced in two places on opposite sides, and the melted sulphur poured out through one of the openings thus made. That which remains will be found beautifully crystalline. The *native* crystals obtained from Italy are sometimes two or three inches in diameter. Some of their forms are represented in the accompanying figures.

Fig. 49.

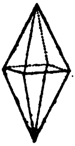


Fig. 50.

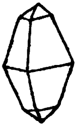


Fig. 51.

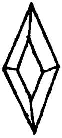
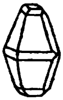


Fig. 52.



131. The range of combination of sulphur is very wide, and its compounds are very important. *Sulphurets** are compounds of sulphur with electro-positive or inflammable bodies. *Sulphates* are salts containing sulphuric acid; *sulphites*, salts containing sulphurous acid. Sulphur is of great importance in the arts. It is one of the ingredients of gunpowder, and forms the basis of all kinds of matches. The most important of the acids, sulphuric acid, is made from sulphur. Sulphur is also a valuable agent in medicine.

SELENIUM.

132. Selenium resembles sulphur in many of its properties. It is brittle, and so soft as to be easily scratched. It softens when heated, becomes semi-fluid at 212° and perfectly fluid at a somewhat higher temperature. In cooling it remains soft for a long time, and may be worked like sealing-wax and drawn out into long, elastic, transparent threads. Its affinity for oxygen is less than that of sulphur. When gently heated in the air it sublimes without change, and does not take fire until more strongly heated, as by contact with flame. It then

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*These salts are now very generally called *sulphides*.

131. What is said of the range of combination of sulphur and the importance of its compounds? What is meant by the term sulphuret?—the term sulphate?—the term sulphite? What are some of the uses of sulphur?

132. What body does selenium greatly resemble? Mention some of its properties. How does its affinity for oxygen compare with that of sulphur? What is the action of heat upon selenium? Is selenium an abundant or a rare substance? Where has it been found?

burns in the air with a reddish-blue flame, and in oxygen gas with a flame which is white below and bluish-green above.

Selenium is one of the least abundant of the elements, but is found in minute quantity in several ores of copper, silver, lead, bismuth, tellurium, and gold, in Sweden and Norway. It has also been found in the Lipari islands, associated with sulphur, and is contained in the red matter deposited from some kinds of sulphuric acid, especially after the acid has been diluted with water.

PHOSPHORUS.

133. The most remarkable quality of phosphorus is its great inflammability.(40) From its property of emitting light in the dark, by slow combustion, it derives its name, which signifies "light bearer." The term phosphorescence, which applies to a large class of bodies, has a similar origin.(41)

Phosphorus is almost colorless, transparent after slow cooling, and semi-opaque after rapid cooling. It may be cut with a knife,* and the fresh surface has a waxy lustre. It fuses at 113°, and in the fused state presents the appearance of a transparent oil. After fusion it cools, if at rest, down to 97° before it solidifies, and when solidification takes place its temperature rises again to 113°. It boils at 550°, and is converted into a colorless vapor. When rubbed or heated to about the temperature of 110°, it takes fire and burns with great rapidity, emitting an abundance of acid fumes.(42) In oxygen its combustion is so intensely brilliant that the eye can hardly bear the light.(43)

Phosphorus has a variety of uses, but the most important purpose which it serves is in the structure of the human frame, and in that of all land animals. Phosphorus, in the form of phosphate of lime, is found wherever strength and rigidity in the animal frame are required. The internal bony portions of the ear, where the greatest solidity is required, are the densest parts of the skeleton, and phosphate of lime enters most largely into the composition of these bones. The enamel of the teeth consists almost wholly of phosphate of lime.

*This should be done under water.

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133. What is the most remarkable property of phosphorus? Whence does it derive its name and what does this signify? What are some of its properties? At what temperature does it take fire when rubbed or heated? What are some of the uses of phosphorus? Write the symbols and combining numbers of the pyrogens.

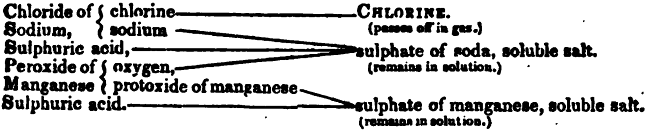
The following table contains the symbols and combining numbers of the pyrogens:

Sulphur,	S.	16 (16·12).
Selenium,	Se.	40.
Phosphorus,	P.	16 (15·72).

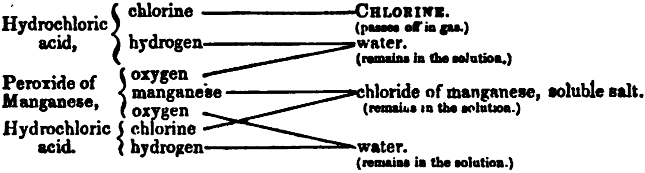
CHLORINE.

134. The great natural source of chlorine is common salt, (chloride of sodium,) of which it composes about 60 per cent. Into a retort are put 3 parts of salt and 1 of oxide of manganese. The mixture is well shaken, and 2 parts of sulphuric acid, previously diluted with 2 of water, added. Chlorine is evolved, and the extrication may be quickened by the application of a gentle heat.

Into the retort were put



135. This method of obtaining chlorine is largely used in the arts in preparing this gas for bleaching linen and cotton goods, and rags for the manufacture of paper. On a *small scale*, the following method will be found more convenient. Provide a flask with a tube bent twice at right angles, and passing through a cork which fits tightly in a flask. From the flask the tube passes into a bottle, and should be of sufficient length to reach nearly to the bottom of the bottle. Into the flask put one part of black oxide of manganese, and pour upon it 2 parts of hydrochloric acid. The chlorine will issue abundantly, and may be received in the bottle by the displacement of air. Towards the latter part, the process may be hastened by the application of heat.



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134. What is the great source of chlorine? Explain the method of preparing chlorine from common salt.

135. Explain the common process of obtaining chlorine for experiment.

136. Chlorine is a yellowish green gas.(44) It has an astringent taste and a disagreeable odor.(45) It is one of the most suffocating gases, exciting spasms and great irritation in the throat and lungs, and should not be incautiously breathed, even when considerably diluted with air. Some relief from the sensations produced by it, may be obtained by inhaling the vapor of ether or alcohol. If a mouse, or other small animal, be dropped into a jar of chlorine, it will instantly fall dead. Mingled with hydrogen it becomes explosive, and may be inflamed by the direct rays of the sun.(46) It is about two and one half times heavier than air.(47) Under the pressure of about four atmospheres, it is a limpid fluid of a bright yellow color. Cold water, recently boiled, absorbs twice its volume of chlorine, and yields it again when heated.

137. Chlorine unites with some substances with the evolution of light and heat, and hence is called a *supporter of combustion.* On plunging a lighted taper into chlorine, it burns for a short time with a small red flame, aud emits a large quantity of smoke. It may be relighted, if the wick is large and red hot when introduced into the gas. Phosphorus takes fire in it spontaneously, and burns with a pale white light. Melted sulphur also takes fire in chlorine, and burns rapidly. Several of the metals, such as tin, copper, arsenic, antimony, and zinc, when introduced into chlorine, in a state of powder or of fine leaves, are suddenly inflamed.(48) Chlorine is indirectly one of the most powerful oxidizing substances which we possess. It oxidizes by withdrawing the hydrogen, for which it has a great affinity, from the water in which different substances are dissolved, and thus the oxygen of the water being set free, unites with the substances in solution. This process always oxidizes bodies that have a strong affinity for oxygen.(49)

138. *Chlorine bleaches and destroys all the colors derived from the animal or vegetable kingdoms.* In consequence of this property, chlorine has become a most important agent in bleaching. Linen, cotton, paper, and other materials,

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136. What are some of the properties of chlorine? What is its effect on a mouse or other small animal? How may a mixture of chlorine and hydrogen be inflamed? What is the specific gravity of chlorine? Under what pressure does it become fluid? To what extent is it absorbed by cold water? What is the effect of heat on chlorine water?

137. Why is chlorine called a supporter of combustion? What effect has this gas upon a lighted taper?—on phosphorus? What other examples are mentioned of bodies that take fire spontaneously in chlorine? In what way does chlorine effect the oxidation of bodies?

may now be rendered perfectly white by it in a few hours, while, by the old method of laying them on the grass in the sun, weeks, and even months, were required to produce this effect. Chlorine is not, however, used directly, as it would be injurious to the health of the laborers, but *chloride of lime* is employed, a salt from which the chlorine is separated by mere exposure to the air.(50)

139. Chlorine is one of the best and most powerful substances that can be used for the purposes of disinfection; but its use for this purpose requires care. Bleaching powder, mixed with water, and exposed to the air in shallow vessels, becomes slowly decomposed by the carbonic acid of the atmosphere, and the chlorine is evolved. If a more rapid disengagement of chlorine be wished, a little acid of any kind may be added, but an excess of chlorine is as bad as the gases it is designed to remove. It disinfects the air by decomposing the noxious gases, uniting with one of the constituents, and precipitating the other in the solid or harmless form. Several of the gases to be described hereafter, as sulphuretted hydrogen, are decomposed in this way.

IODINE.

140. Iodine is an element found in the ashes of sea-weed and of sponge. In general characters it is similar to chlorine. It is a soft, friable, opaque solid, of a bluish-black color, and metallic lustre. It has a pungent odor, an acrid taste, and stains the skin of a deep brownish color. It destroys to a certain extent the vegetable colors. It is not very soluble in water(51), unless the water is impregnated with salt. In this case a larger quantity is dissolved. It is soluble in ether and alcohol. Its vapor is about eight and one half times heavier than air (sp. gr. 8·7), hence it will remain in a bottle in which it is volatilized, or it may be poured by inclining the bottle in a stream of dense red vapor.

Potassium and sodium, and several other bodies, burn in iodine. It is therefore regarded as a *supporter of combustion*, although its agency in promoting combustion is exceedingly limited.(52)

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138. What is said of the bleaching properties of chlorine? What salt of chlorine is employed in the process of bleaching?

139. What is said of chlorine as a disinfectant? In what manner does chlorine disinfect the air?

140. Where is iodine found? What element does it resemble in its general character? What are some of its properties? What is the specific gravity of its vapor? Why is iodine regarded as a supporter of combustion?

141. One of the most characteristic properties of iodine is the production of a splendid blue color, with starch. The iodine for this purpose must be free or uncombined, and the solution of starch cold. To set free the iodine when combined, it is merely necessary to add chlorine water or nitric acid, which takes the base, and if this be done in a solution of starch, the blue color is instantly produced. By this test iodine may be detected in water containing the $\frac{1}{40,000}$ part. If a little iodine tincture be dropped upon flour, potatoes, &c., the presence of starch in these substances will be at once indicated.

Iodine is consumed in large quantities in medicine. It is employed as pure iodine, and as iodide of potassium, but if not administered cautiously, and in very small quantities, it is an irritant poison. The vapor of iodine is employed in rendering daguerreotype pictures sensitive to light, as will be explained hereafter.

BROMINE.

142. Bromine is found in very minute quantities in sea-water, and in the ashes of certain medicinal plants. It is a brownish red liquid of a powerful and suffocating odor, emitting red fumes. This vapor is about six times as heavy as air (sp. gr. 5·93). Sulphuric acid floats on the surface of bromine, and is used to prevent its escape. It freezes at zero into a brittle solid. It causes phosphorus to burn, and combines with many metals with ignition. The flame of a burning taper, immersed in the vapor of bromine, appears red at the top and green below. It is therefore regarded as a *supporter of combustion*, although most bodies are extinguished when immersed in it. It produces a *yellow color*, with starch.

Both bromine and iodine are the constant attendants of chlorine; wherever common salt occurs, whether in the earth, the sea, or in mineral springs, small quantities of these bodies are found, not in a free state, but combined with metals. The different sea-weeds attract these combinations from sea-water, and from these sea-weeds iodine and bro-

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141. What is one of the most characteristic properties of iodine? In what state must the iodine be to give a blue color with starch? How may it be disengaged if combined? What is the blue compound thus produced? Ans. the *iodide* of starch. What is said of the delicacy of this test for iodine? What are some of the uses of iodine?

142. Where is bromine found? What are some of its properties? What is the specific gravity of its vapor? What is used to prevent its escape? At what temperature does it become solid? Why is bromine called a supporter

mine are extracted. Both these bodies have poisonous properties. One drop of bromine administered to a bird, through the beak, is sufficient to cause death. A small quantity of bromine imparts a transient yellow color to the skin; a larger quantity produces a yellow and then a brown color, which can be removed only with the skin itself. In still larger quantity it produces immediate corrosion of the part to which it is applied, and violent inflammation. It corrodes also wood, cork, and other organic substances, imparting a yellow color to them. Like chlorine, it rapidly bleaches tincture of litmus and indigo.

FLUORINE.

143. It is doubtful whether fluorine has ever been obtained in a separate state. Its compounds can easily be decomposed, but its remarkable energy of combination with the metals, and especially with silicon, a constituent of glass, has rendered its isolation very difficult. When one of its compounds is decomposed, it passes almost instantly into some other, and cannot be retained in the free state. It has been, however, proved to be a gas of a yellowish brown color, having the smell and bleaching properties of chlorine. It probably holds an intermediate place between oxygen and chlorine.

Symbols and combining numbers of the halogens:

Chlorine,	Cl.	35.
Iodine,	I.	127 (126·57).
Bromine,	Br.	78.
Fluorine,	F.	19.

These substances have a *far greater* affinity for hydrogen than for oxygen. With hydrogen they form acids (hydrogen acids), and with the metals salts, which are called *haloid salts*, to distinguish them from the common or *oxygen salts*.

SILICON AND BORON.

144. Both of these subtances occur in nature only in combination with oxygen; boron but seldom, as in boracic

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of combustion? What is said of the origin of bromine and iodine? What is said of their poisonous and corrosive properties? Does bromine possess bleaching properties?

143. Why is it difficult to obtain fluorine in a free state? What are some of its properties? Between what two gases is it supposed to belong? Write the symbols and combining numbers of the halogens. What kind of acids do these elements form? What are their salts called? Why are they so called?

acid, or borax, and silicon very abundantly, as in sand, quartz, and almost all kinds of stones.

Silicon has a nut-brown color. Heated in the air it burns, but it is never more than partially converted into silica. It also burns when heated in the vapor of sulphur, and in chlorine. By heat alone silicon is changed to an *allotropic* form, or to a form possessing the same composition but different properties. It becomes, when heated, darker colored, denser, and incombustible even under the compound blowpipe. This change in its properties takes place when heated *without contact of air*, or in a covered crucible.

Boron is a dull greenish-brown powder. When heated in the air, or in oxygen, it burns with a vivid light, scintillating powerfully, and forms by its combustion boracic acid. It is at once attacked by nitric acid, chlorine, alkalies in a fused condition, and other agents. When mixed with saltpetre and heated, it explodes.

Symbols and combining numbers of the hyalogens:

Silicon,	Si,	22.
Boron,	B,	11.

ACID COMPOUNDS OF THE NON-METALLIC ELEMENTS.

145. The *compounds* of the non-metallic elements may be divided into acid, neutral, and alkaline. By the term acid is meant a substance that is sour, reddens vegetable blues(53), and neutralizes the alkalies.(54) Alkalies are those substances that have an acrid taste and caustic properties; that change vegetable blue infusions to green, or yellow to brown, and that neutralize acids.(55) Neutral substances are those which possess neither the properties of acids nor alkalies, and are sometimes produced by the action of acids on alkalies, by which the peculiar properties of each

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144. What are the sources of silicon and boron? Do they ever occur except in combination with oxygen? What are some of the properties of silicon? How do the two forms of silicon differ from each other? How may the second form be produced from the first? What are some of the properties of boron? Write the symbols and combining numbers of the hyalogens.

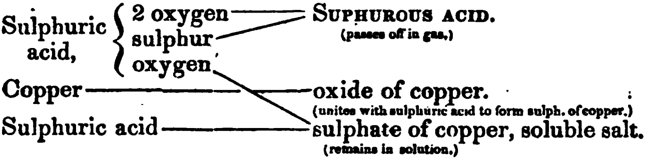
145. In what manner may the compounds of the non-metallic elements be divided? What is meant by the term acid?—alkali? What is a neutral substance?

component are destroyed in the resulting compound. These substances are called salts, and form a very important class of bodies.(56)

146. The most important of the acid compounds of the non-metallic elements are, sulphurous and sulphuric, nitrous and nitric, phosphorous and phosphoric, carbonic, hydrochloric, chlorous and chloric, hyposulphuric or sulphuretted hydrogen, hydrofluoric, and silicic.

	Sulphur.	*Oxygen.*	*Symbol.*
SULPHUROUS ACID,	16	16	SO_2
SULPHURIC ACID,	16	24	SO_3

147. *Sulphurous acid* is found in the neighborhood of volcanoes, both in the gaseous state and in springs. It is the only product of the combustion of sulphur in the air, or in oxygen gas. It is most conveniently prepared by heating copper clippings, or metallic mercury, with sulphuric acid in a retort. The copper, or mercury, decomposes the sulphuric acid, taking one third of its oxygen, and the sulphuric acid becomes sulphurous. *In numbers*, from SO_3 (sulphuric acid) take O, there remains SO_2 (sulphurous acid.)



148. Sulphurous acid is a colorless gas, having the peculiar suffocating odor of burning brimstone. It is acid in its taste, and reddens litmus paper, or vegetable blues. It has the power of checking vinous fermentation, and it is therefore employed in the process of brewing and mixing wine. It also possesses bleaching properties. Litmus paper after being reddened by the acid fumes, is slowly bleached.(57) The fumes of burning sulphur are employed to whiten straw and to bleach silk, and they also impart to these substances a peculiar gloss. The colors are not, however, *destroyed*, for they may, in general, be restored by the application of a stronger acid, or an alkali. Sulphurous acid extinguishes

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147. Write the composition and symbol of sulphurous acid ;—sulphuric acid. Where is sulphurous acid found in nature ? How is it easily produced ? Describe the method by which it is prepared for experiment.

148. What are some of the properties of sulphurous acid ? For what purposes is it sometimes employed ? Does it destroy vegetable colors permanent-

burning bodies. The burning soot of a foul chimney may be extinguished by throwing sulphur on the fire, and thus filling the chimney with the fumes of sulphurous acid. It is speedily destructive to animals placed in it.(58) It is the easiest of all gases to *condense into the liquid form*, requiring for this purpose only to be passed in a dry state through a glass tube surrounded by a freezing mixture of snow and salt. The same effect may be produced by exerting on it a pressure of two atmospheres while at the freezing point.

Water at 60° is capable of dissolving nearly 50 times its volume of sulphurous acid, forming a strongly acid fluid. Its avidity for moisture is so great, that it forms an acid fog with the moisture of the atmosphere, and a bit of ice slipped under a jar of sulphurous acid is instantly melted and absorbs the gas, the mercury rising to fill the jar.

149. Sulphurous acid is easily converted into sulphuric. All that is required is the presence of oxygen gas and water. A mixture of sulphurous acid and oxygen may be kept for a long time over mercury without chemical action; but if water be admitted, sulphurous acid gradually unites with the oxygen, and is converted into sulphuric acid. This property of sulphurous acid is of great importance, as on this the process for making sulphuric acid, on the large scale, depends. From its affinity for oxygen, sulphurous acid decomposes the solutions of those metals which have a weak affinity for oxygen, such as solutions of gold, silver, and mercury (with heat), and throws down these bodies in a metallic form. By nitric acid it is immediately oxidized and converted into sulphuric acid.

150. *Sulphuric acid.* This is the most important of all the acids. It has all the acid properties in a high degree. When pure, it is a limpid, colorless fluid, nearly twice as heavy as water. It boils at 620°, and freezes at 15°. When combined with water, so that its specific gravity is 1·78, it freezes at as high a temperature as 40°, but any further addition of either water or acid, causes the temperature of its freezing point to sink.

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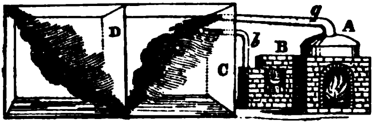
ly? What effect does it produce on burning bodies? How may a burning chimney be extinguished? What is its effect on animal life? How is it condensed into the liquid form? To what extent is sulphurous acid absorbed by water? What is said of its avidity for moisture?

149. What is necessary for the conversion of sulphurous acid into sulphuric? By what experiment is this illustrated? What effect has sulphurous acid on solutions of metals which have a weak affinity for oxygen? How does it decompose these solutions? In what form are the metals thrown down?

150. What are some of the properties of sulphuric acid?

151. The process for the *manufacture of sulphuric acid*, depends upon a property of sulphurous acid mentioned above, viz., that of being readily converted into sulphuric acid, by the presence of *both* oxygen and water. To understand this process, it will be necessary to learn first, the source of the sulphurous acid; secondly, that of the oxygen; and thirdly, that of the water.

Fig. 53.



A and B (Fig. 53.) are two furnaces; C and D two gas chambers. On the floor of the furnace, B, sulphur is strewn. This is set on fire, and the fumes thus produced are *sulphurous acid*, which pass through the chimney, *b*, into the chamber, C. In the furnace, B, is seen a tripod, and upon this an iron dish. This iron dish, or capsule, contains sulphuric acid and saltpetre. The flame of the sulphur beneath the capsule, causes nitric acid gas to be given off (from the decomposition of the saltpetre, or nitrate of potash), which also passes through the chimney, *b*. This is the source of the oxygen, the second element to be obtained, for nitric acid contains a large amount of oxygen (p. 96), and this is absorbed and taken away from the nitric acid in the process.

Finally, *water* is obtained in the form of steam from the boiler, A, and passes through the pipe, *g*, into the chamber, C. In this chamber, therefore, are all the substances necessary for the composition of sulphuric acid;—the *sulphurous acid* from the burning sulphur in B;—the oxygen from the nitric acid gas formed by the materials in the iron capsule;—the watery vapor from the boiler, A. These unite in C, and any excess flows into a second chamber, D, &c. The acid collects on the floors of these chambers. When it has attained a certain degree of strength, which is regulated by admitting more or less steam into the chamber, it is drawn off and concentrated by evaporation; first in leaden pans, and afterwards in stills of platinum, until it attains a specific gravity of about 1·84. It is then transferred into carboys, or large glass bottles fitted into baskets, and ready for sale. In Great Britain, the manufacture of sulphuric acid is one of great national importance, and is carried on to a vast extent.

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151. Explain Fig. 53.

152. The attraction of sulphuric acid for bases* is such, that it separates and expels all other acids from their combinations.(59) Its affinity for water is so great, that it absorbs it from the atmosphere. When dilute acid is boiled, pure water is given off at first, and no acid vapor mixes with the vapor of water till it is brought to the proportion of 2 atoms of water to 1 of acid, when the acid evaporates unchanged. When mixed with water, *the volume* of the mixture is condensed, and its temperature rises above the boiling point of water, so that water placed in a small test tube, in this mixture, boils; a test tube containing alcohol, or ether, will boil more violently.(60)

A contrary effect is produced by adding sulphuric acid to snow.† The most intense cold is instantly produced by the sudden change of the snow to the liquid form of water. Water added to snow dissolves it but gradually, but the acid melts a large quantity at once, and the great amount of heat which thus becomes latent, is absorbed from the bodies with which the snow is in contact.

153. Sulphuric acid chars and destroys most vegetable and animal substances. If a piece of wool be introduced into this acid, it grows black, and is reduced to coal, almost as if it had been exposed to the flame of a lamp. The sulphuric acid seizes upon its hydrogen and oxygen, which combine to form water, and unite with the acid, while the carbon remains. Wood may be charred in this way, in order to protect it from decay in moist situations. In the refining of burning oil, the slime of the oil is charred by sulphuric acid.

Sulphuric acid may be detected in exceedingly small quantities by any of the soluble salts of barium. If a few drops of the acid be added to a test tube, or a wine glass of water, and a little baryta water be added, a dense white pre-

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* The substances with which acids combine, either alkalies, earthy substances, or metallic oxides.

† One part of sulphuric acid with one part of snow, evolves *heat;* with one and one quarter parts of snow, no change of temperature occurs, and with a larger quantity intense cold is produced.

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152. What is said of the attraction of sulphuric acid for the bases of salts? What is said of its affinity for water? What takes place when water is added to sulphuric acid? Ans.—The volume of the two substances is diminished and the temperature rises above the boiling point of water. What effect is produced by adding sulphuric acid to snow? To what is the intense cold of this mixture owing?

153. What is the action of sulphuric acid on animal and vegetable substances? Why is wool blackened and charred by sulphuric acid? What tests are employed to detect sulphuric acid? How much sulphuric acid is indicated by

cipitate is formed. Every 100 grains of this precipitate indicate 34 grains of sulphuric acid. Water containing the $\frac{1}{100,000}$ part of sulphuric acid, is rendered slightly turbid by the addition of nitrate of baryta; and water containing the $\frac{1}{200,000}$ part, is slightly clouded after the lapse of 15 or 20 minutes.

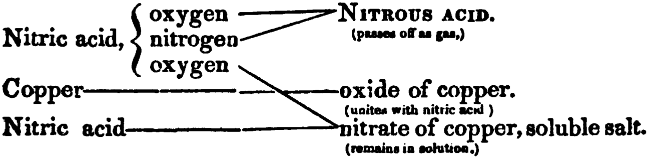
154. If a meadow or field be irrigated with one pound of sulphuric acid, diluted with 100 pounds of water, the soil will be rendered more fertile and productive. The sulphuric acid acts to decompose and render soluble several kinds of earth, and the soluble sulphates thus formed are absorbed by the plants, and accelerate their growth. If only 10 times diluted, sulphuric acid has the contrary effect, and may serve for destroying grass, and weeds in alleys, &c.

Sulphuric acid probably exists combined with the water of certain volcanic springs. It is found in large quantities, both in the organic and inorganic kingdoms.

	Nitrogen.	*Oxygen.*	*Symbol.*
HYPONITROUS ACID,	14·06	24	NO_3.
NITROUS ACID,	14·06	32	NO_4.
NITRIC ACID,	14·06	40	NO_5.

155. *Hyponitrous acid.* This substance is important only in its relations to nitric oxide; it will therefore be considered, in connection with that gas hereafter.

156. *Nitrous acid* is obtained by the action of nitric acid, diluted with about two parts of water, on metallic copper, *with the presence of air*, from which oxygen is absorbed during the process.



The gas is copiously evolved, and may be collected in dry vessels by the displacement of air. It has a characteristic orange red color. It cannot be breathed, and excites great

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100 grains of its precipitate with baryta? What is said of the delicacy of the test with nitrate of baryta?

154. Why is a very weak solution of sulphuric acid favorable to the growth of plants? What effect has a strong solution? Where is it probable that sulphuric acid exists? Where is it found in large quantities?

irritation in the throat and lungs, even when diluted with air. Bodies which burn with great intensity, as phosphorus, decompose this gas, and therefore their combustion is continued by the great amount of oxygen which it contains. Ignited charcoal produces the same effect, but a taper, or burning sulphur, will be extinguished. Its density is 1·451, air being 1,000; it is therefore about one half heavier than air. The power of water to absorb this gas, may be shown while the gas is collecting, by stopping the neck of the receiver around the glass tube with wet cotton or sponge. Even after the receiver is full of gas, none will escape into the room, the excess being absorbed by the wet cotton.(61) Nitrous acid destroys life. An animal dropped into this gas instantly dies.

The relations of nitrous acid to light are very remarkable. When its temperature is very low it is nearly colorless, but it takes an orange tint as the degree of heat increases, and finally become almost black. If it is examined while undergoing these changes, by passing a ray of light through it, and analyzing the ray by means of a prism, a great number of dark lines are found in the resulting spectrum; as the temperature rises, these increase so much in number and in breadth, that the light finally becomes obliterated.

157. *Nitric acid* is the most important *compound* of oxygen and nitrogen. When pure it is perfectly colorless, but when exposed to the rays of the sun it becomes yellow from partial decomposition, and, on loosening the stopper of the bottle, it is projected with force by the gas produced by decomposition. To preserve the acid colorless, it must be kept in a covered bottle.(62) The yellow color may be driven off by heat, and the acid rendered again colorless. It is intensely corrosive and sour, and fumes when exposed to the air. It is one half heavier than water (sp. gr. 1·51). Its action on metallic and other combustible bodies is exceedingly violent, owing to the great amount of oxygen which it contains. A little water must, however, be present in the acid, as very strong acid seems to have but little power in this respect. Organic substances, also, as sugar and starch, decompose with nitric acid and cause an evolution of abun-

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155. Write the composition and symbols of hyponitrous, nitrous, and nitric acids. Explain the method of obtaining nitrous acid. What are some of its properties? What bodies burn in nitrous acid? What other properties of nitrous acid are mentioned? What is its effect on animal life? What is said of its relations to light?

157. What are some of the properties of nitric acid? In what manner may this acid be preserved colorless? How may its yellow color be driven off?

dance of red fumes.(63) It boils at 248°, and freezes at about 40° below zero. When diluted with half its weight of water it becomes solid at 12° below zero, and with a little more water its freezing point is again lowered to —45°. It causes ice and snow suddenly to melt, producing intense cold. Hence this is one of the most common freezing mixtures. It will sink the thermometer from 12° above to 30° below zero.

Nitric acid cannot be isolated from water, or from the bases with which it is combined. It is doubtful whether the proportion of *constitutional* water with which it is combined, can be reduced below 13 equivalents. It attracts moisture from damp air, and increases in weight. When suddenly mixed with ¾ its weight of water, it rises in temperature from 60° to 140°. The large amount of oxygen which nitric acid contains it yields with great facility. It is, therefore, very useful to the chemist in processes for obtaining oxygen, or in imparting oxygen to other substances, as in the formation of several of the acids. Nearly all the metals are oxidized by it, and some of them with extreme violence; such as copper, mercury, and zinc, in the concentrated acid. It is much used in the arts by engravers for etching their copper plates, in the solution of metals, and in dyeing. It has also important uses in medicine. In its concentrated state it is a deadly poison, corroding and destroying the animal organs.

It cannot be detected by the precipitation of its compounds, since these are all soluble. One of the best tests is its power of bleaching sulphate of indigo, when boiled with that liquid; to remove doubt from the result, it is necessary to decide that chlorine is not present, which may be done by the tests for chlorine. The tint which nitric acid gives to hydrogen flame, is one of the means for detecting its presence. For this purpose a few fragmants of zinc and sulphuric acid are added to the nitrate or the body supposed to contain nitric acid. If nitric acid be present, on setting fire to the hydrogen formed from the zinc and sulphuric acid, a greenish tinge will be given to the flame. Another test for nitric acid is the formation of *aqua regia** when hydrochloric acid is

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* A mixture of nitric and hydrochloric acid, which will dissolve gold and platinum.

What is said of its action on metallic and other combustible bodies? What is essential to this action? What is its action on organic substances? What other properties of nitric acid are mentioned? Can nitric acid be separated from water or the bases with which it is combined? What is meant by the added to its solution. If this is formed by the addition of hydrochloric acid, which may be determined by placing some gold leaf in the solution, nitric acid is present.

Nitric acid forms transparent colorless crystals of great brilliancy, having the form of prisms with six faces. (166.) When slowly deposited from a current of gas, they attain a considerable size. They melt at a little above 85° and boil at 113°. When water is added they dissolve completely, causing a great rise of temperature.

	Phosphorus.	*Oxygen.*	*Symbol.*
PHOSPHOROUS ACID,	31·38	24	PO_3.
PHOSPHORIC ACID,	31·38	40	PO_5.

158. *Phosphorous acid.* The white fumes which arise from the slow combustion of phosphorus are phosphorous acid. It is also formed when phosphorus is burned in a very limited supply of air or oxygen gas. It is an acid of very little importance. It forms white and very bulky masses, easily volatilized and sublimed, having a very strong affinity for water, which it absorbs, together with oxygen, from the air, and gradually becomes phosphoric acid. It has a garlic smell. Its solutions are sour, and it forms well determined salts. It is, therefore, strongly acid in its properties. On account of its strong affinity for oxygen, the solution of this acid is sometimes used as a deoxidizing agent.

159. *Phosphoric acid.* The method by which nitrogen and phosphoric acid are prepared at the same time, has been described under the head of nitrogen. (108.) This acid is a colorless gas, possessing strongly the acid properties. If it be collected from the inside of a jar in which it is formed, and quickly put into a dry watch glass, and a few drops of water be added to it, the water and the acid will combine with explosive violence, producing great heat, accompanied by a hissing sound. Once in a state of hydrate, the water cannot again be separated from it. This acid is not poisonous, neither does it corrode the skin. At a high furnace heat, charcoal decomposes phosphoric acid by abstracting its oxygen, and the phosphorus sublimes. This may be collected by immersing the neck of the retort under water.

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phrase water of constitution? Ans. That water, without which the body cannot exist, or a separation from which is always attended by its decomposition. What is said of the relations of nitric acid to oxygen? What uses are made of nitric acid? What are some of the tests for this substance?

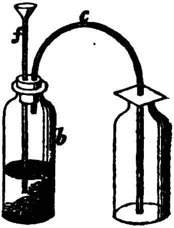
158. Write the composition and symbols of phosphorous and phosphoric acids. How is phosphorous acid formed? What are some of its properties?

159. How is phosphoric acid produced? What are some of its properties?

	Carbon.	*Oxygen.*	*Symbol.*
CABRONIC ACID,	6	16	CO_2.

160. For preparing carbonic acid, a wide-mouthed bottle, *b*, (Fig. 54.) is provided with a bent tube, *c*, passing through its cork, and a funnel tube, *f*. Pieces of white marble, or chalk, are placed in the bottle, which is then stopped, and a little water poured in through the funnel. When the end of the funnel tube is covered with water, hydrochloric acid is added, and the gas comes over and may be collected in dry bottles, as represented in the figure. A piece of pasteboard is placed over the bottle to prevent the agitation of the air from affecting the gas within.

Fig. 54.



Carbonic acid is colorless and inodorous, and about a half heavier than air, (sp. gr. 1·524).(64) Even when diluted with three times its volume of common air, it extinguishes a candle. By the pressure of 36 atmospheres, or 540 pounds to the square inch, it may be converted into a liquid. When the pressure is removed, the liquid resumes the gaseous state with such rapidity as to freeze that which is left. This sudden expansion into the gaseous state absorbs so much sensible heat, or converts so much sensible heat into latent, that bodies with which it is in contact are reduced to a temperature of 148° below zero.

At —85° carbonic acid is frozen into a white flocculent mass, resembling snow, and compressible like that substance. When exposed to the air, the acid disappears in a few minutes, and often leaves behind a small quantity of water, condensed from the air by the cold. If the snow is touched with the finger, when resting on a smooth surface, it glides quickly forward, as if supported by a stratum of gas. A piece of solid carbonic acid pressed upon the skin of an animal, stops the circulation at the point of contact by the cold which it produces, forms a white spot, and after fifteen seconds, a blister. If some of the snow is introduced into a capsule containing mercury, and wet with ether, the mercury is frozen solid, and can be hammered and drawn out like lead. If it is moistened with ether in a vacuum, a cold of —174° may be obtained.

At common temperatures and pressures, water absorbs its

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160. Write the composition and symbol of carbonic acid. Explain Fig. 54. What are some of the properties of carbonic acid? At common temperatures and pressures how much carbonic acid does water absorb? What effect does

own volume of carbonic acid; under a pressure of two atmospheres it absorbs twice its own volume, &c. It is found in mineral springs, to which it imparts their effervescence, and their slightly pungent taste. The insipid character of boiling water is owing to the absence of carbonic acid. It does not support combustion, and is hostile to life.(65) If three jars be placed alongside of each other, one containing carbonic acid, the second oxygen, and the third common air, a candle will be put out in the first, relighted in the second, and will burn as usual in the third. Ignited potassium, however, burns in carbonic acid by decomposing the gas, taking the oxygen and depositing the carbon in a fine black powder.

The Grotto del Cane,* in Italy, is a cave so called because a dog is used to show the effects of the carbonic acid within the cave. It is situated on the bank of a lake, and a stream of warm water flows from it, accompanied with vapor and smoke. Above the water, and on its surface, a stratum of carbonic acid rolls out from the cave. Being heavier than air, this does not rise, and therefore a man may walk in the cave and experience no inconvenience, but a dog soon drops down and dies unless drawn out to the air. So perfectly distinct does the stream of gas flow out from the cave, and to a distance beyond it, that the smoke above the current marks its course, and rises and falls with the inequalities of the ground.

Carbonic acid is produced in all the processes of fermentation, and it is this gas which gives the foam and life to beer and other fermented drinks. In raising bread, carbonic acid is generated by the fermentative process; and in baking, this, becoming entangled in the dough, renders the bread light and porous. It is also produced in the ground by the fermentation of animal and vegetable matter. This is the origin of the *choke damp* of wells. Many accidents have occurred from persons descending into such wells. Meeting with carbonic acid they are suffocated, and fall into the well. A candle should always be let down into a well before descending into it. If the candle goes out, the air of the well is charged with carbonic acid. Even if the candle does not go out, the air may be so contaminated with carbonic acid as to render it injurious if breathed for a long time. This gas may be removed from wells by lowering down a quantity of recently ignited charcoal, or quicklime mixed with water. It may also be pumped out by a pump furnished with a leather hose.

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* Grotto of the dog.

the presence of carbonic acid in mineral springs produce ?—in common water? What are the relations of carbonic acid to combustion and life? What substance burns in carbonic acid? How does the combustion of potassium in carbonic acid take place? Describe the Grotto del Cane in Italy? In what processes is carbonic acid produced? In what manner is bread rendered light?

Carbonic acid is one of the products of the combustion of our fires. As this, and all the other gases given off in combustion, are deadly in their nature, great care should be taken that none of the fumes from stoves or fire-places escape into the room. When charcoal is burnt, it should be under the draught of a chimney. Many persons have lost their lives from the fumes of charcoal burning freely in a room.

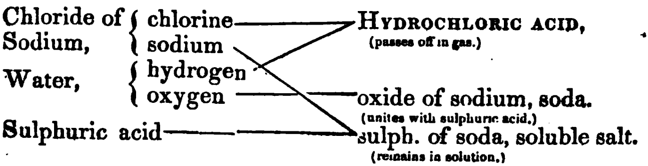
The affinity of carbonic acid for most bases is so weak that it is driven off by heat. Lime is made in this way by roasting limestone (carbonate of lime), by which the carbonic acid is driven off, and caustic lime left.

Carbonate of lime is soluble in water containing carbonic acid, but when the carbonic acid is driven off from such water, or diminished by heat or otherwise, the carbonate of lime is deposited. From this cause arise the vast calcareous deposits and concretions called stalactites, stalagmites, &c., which are found in caverns and similar places.(66)

The presence of carbonic acid is always determined by adding any other acid. If present it will be indicated by its effervescence, or by the sparkling appearance on the sides of the glass, or on the surface of the liquid.

	Hydrogen.	*Chlorine.*	*Symbol.*
HYDROCHLORIC ACID,	1·00	35·41	HCl.

161. This acid is formed by the action of dilute sulphuric acid on common salt. A little heat is applied, and the gas is collected in dry vessels by the displacement of air.



What is the choke damp of wells? How may its fatal effects be avoided? What is another source of carbonic acid? Should charcoal or any other fuel ever be allowed to burn freely in a room? How may carbonic acid be driven off from most of its bases? How are the stalactites and other calcareous concretions of caverns formed? How may the presence of carbonic acid be determined?

161. Write the composition and symbol of hydrochloric acid. Explain the

In the arts, hydrochloric acid is made in connection with other processes, particularly in the manufacture of carbonate of soda from common salt. It was formerly allowed to escape into the air, but it was found to produce such deleterious effects upon the vegetation and the animals in the vicinity, that it was required by law to be condensed. It was sometimes detected in the air at the distance of two miles from the manufactory. Such quantities are now manufactured as greatly to reduce its price, and sometimes even to overstock the market.

Hydrochloric acid may be produced by the direct union of its elements, or by *synthesis*. When equal measures of chlorine and hydrogen are mixed together, and an electric spark passed through the mixture, instantaneous combustion takes place, and hydrochloric acid is formed. Light also causes them to unite.(67) If the mixture be placed in the direct rays of the sun, a sudden union of the chlorine and hydrogen takes place, attended with flame and explosion. The vivid galvanic light on charcoal points (83), produces the same effect. The mixed gases may also be exploded by a match.(68)

When pure, hydrochloric acid is a colorless gas, with a pungent odor, and a sour taste. It is somewhat heavier than air (sp. gr. 1·269). By a pressure of 40 atmospheres, at 50°, it is condensed into a liquid of specific gravity 1·27. It cannot be breathed; but when diluted with air it is far less irritating than chlorine. It extinguishes combustion, and is not itself combustible. One of the most striking properties of hydrochloric acid, is its great attraction for water. A white cloud appears whenever it escapes into the air, owing to its combining with the invisible vapor of the air, and precipitating that vapor. A piece of ice put into a jar full of this gas, disappears in a few moments, and if the jar stands over mercury, this rises in the jar to the top, the water of the melted ice absorbing the gas completely. On opening a wide mouthed jar of hydrochloric acid under water, the absorption of the gas takes place so instantaneously, that the water is forced up into the jar with the same violence as into a vacuum. Heat is produced in this experiment by the condensation of volume which the gas undergoes.

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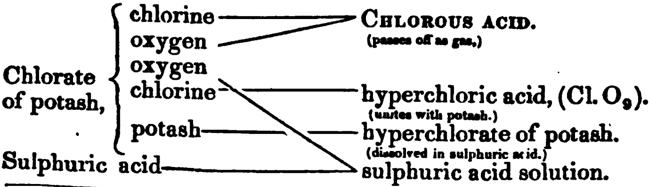
process by which it is obtained. How is hydrochloric acid generally manufactured in the arts? How may this acid be formed by synthesis? What are some of its properties? Mention some of the properties of liquid hydrochloric

Liquid hydrochloric acid, like the gas, is colorless when pure. It emits white vapors when exposed to the air, and possesses the acid properties in a high degree. Like sulphuric and nitric acids, when mixed with water it raises its temperature by a condensation of volume. It boils at 110°, and freezes at 60° below zero. With nitric acid it forms *aqua regia.* The properties of this compound are not those of the acid mixture, but of the chlorine which is set free, and which, in its *nascent state* (p. 64), dissolves gold and platinum.

Hydrochloric acid is a valuable agent in medicine. Besides being used in the liquid form, like other medicines, it is used in the gaseous state as a *disinfecting* agent. For this purpose, it is common in hospitals and in other places of disease, to liberate the hydrochloric acid from common salt by means of sulphuric acid. In the arts it is used chiefly by the dyers in forming colors, and in obtaining chlorine gas (135.) for bleaching. It possesses also valuable antiseptic properties(69), and bleaching powers to some extent.(70) In the laboratory it is very valuable in producing chlorine, in dissolving a great number of metals, and in testing for bodies in chemical analysis.(71)

	Chlorine.	*Oxygen.*	*Symbol*
CHLOROUS ACID,	35·41	32	ClO_4.
CHLORIC ACID,	35·41	40	ClO_5.

162. *Chlorous acid* is obtained by the action of sulphuric or hydrochloric acid on chlorate of potash. The chlorate of potash is made into a paste with sulphuric acid previously diluted with half its weight of water, and cooled; this is introduced into a small glass retort, and very cautiously heated with warm water; a deep yellow gas is evolved, which may be collected by displacement of air or over mercury.



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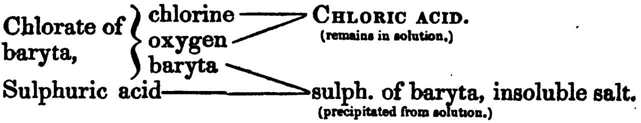
acid. How does aqua regia dissolve gold? What are some of the uses of hydrochloric acid?

162. Write the composition and symbols of chlorous and chloric acids. Explain the process for obtaining chlorous acid. What are some of the proper-

Chlorous acid has a powerful odor, quite different from that of chlorine, which it resembles in color and density. Water dissolves 5 or 6 times its volume of this gas, assuming a golden yellow tint of considerable intensity. It is exceedingly explosive, being resolved with violence into its elements by a temperature short of the boiling point of water. A rag wet with the oil of turpentine at once explodes it. Phosphorus takes fire spontaneously in chlorous acid. Its specific gravity is not quite as great as that of chlorine, being 2·36, while that of chlorine is 2·47. It may be liquefied by pressure. Water absorbs chlorous acid freely. The solution possesses bleaching properties.

When a mixture of chlorate of potash and sugar is touched with a drop of sulphuric acid, it is instantly set on fire, the chlorous acid disengaged being decomposed by the sugar (which takes away its oxygen) with such violence as to set it on fire. If a piece of phosphorus and some chlorate of potash be placed in the bottom of a wine-glass, and the wine-glass filled up with water, the phosphorus may be fired beneath the water by pouring, through a long funnel tube, sulphuric acid upon the mixture. In this experiment the sulphuric acid produces heat, and evolves chlorous acid from the chlorate of potash, which sets fire to the phosphorus. The mixture, at the same time, becomes yellow, from the chlorous acid disengaged, and it also acquires the odor of that gas. If strong sulphuric acid be poured upon a small quantity of crystals of chlorate of potash in a wine-glass, a violent crackling is heard, and the glass is soon filled with the heavy yellow vapor of chlorous acid, which at once inflames a rag wet with turpentine, and produces a smart explosion.

163. *Chloric acid* is formed by adding dilute sulphuric acid to a solution of chlorate of baryta as long as it occasions a precipitate. This precipitate is suffered to subside, and the liquid contains chloric acid in solution.



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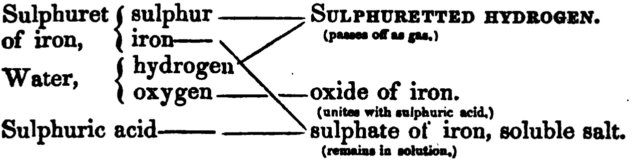
ties of this acid. When sulphuric acid is dropped on a mixture of chlorate of potash and sugar, why does the sugar take fire? How may a mixture of phosphorus and chlorate of potash be fired beneath water? What effect is produced by pouring strong sulphuric acid on chlorate of potash in a wine-glass?

The clear liquid, containing chloric acid, may be poured off and carefully condensed by evaporation. In this state, its affinity for combustible matter is so great, that it immediately inflames any substance containing carbon or hydrogen, with which it comes in contact. Like nitric acid, it cannot be isolated from water or a fixed base. The compounds of chloric acid, or the chlorates, are easily recognized. They give no precipitate with nitrate of baryta or silver. They also evolve pure oxygen when heated, and deflagrate on charcoal. When treated with sulphuric acid they evolve chlorous acid.

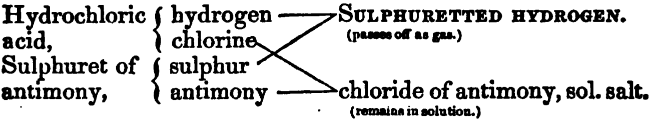
	Hydrogen.	*Sulphur.*	*Symbol.*
HYDROSULPHURIC ACID,	1·00	16·00	HS.

164. This gas is also called *sulphuretted hydrogen.* There are two methods by which it can be readily prepared. In the first, dilute sulphuric acid and sulphuret of iron are employed; in the second, hydrochloric acid and the sulphuret of antimony. The first process yields the gas most easily, the second in the purest state.

Protosulphuret of iron is put into the apparatus used for carbonic acid, (Fig. 54.) Water is poured in through the funnel tube, *f*, sufficient to cover the bottom of the tube; sulphuric acid is then added until a copious disengagement of gas takes place through the tube, *c*, which may be collected in a bottle partly filled with water.



The same arrangement may be employed to generate sulphuretted hydrogen by the second process. A flask should be substituted for the bottle, as heat is to be applied.



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163. Explain the process for preparing chloric acid. Mention some of the properties of chloric acid. In what way may the chlorates be detected?

164. Write the composition and symbol of hydrosulphuric acid. By what

Sulphuretted hydrogen is a colorless gas, of a strong and very nauseous odor. This smell is perceived in the water of sulphurous springs, where this gas is formed abundantly. It is also formed when wet coal is thrown on the fire.* It is a little heavier than air (sp. gr. 1·171). (72) It has feeble acid properties. Under a presure of 17 atmospheres, at 50°, it becomes a highly limpid colorless liquid of specific gravity 0·9. At—122° it is frozen into a white crystaline translucent substance, which is heavier than the liquid. To animal life it is very injurious. Birds perished in air containing only $\frac{1}{1,500}$, and a dog in air containing $\frac{1}{800}$ of this gas. A horse died in an atmosphere containing only the $\frac{1}{250}$ part. It is owing to this fact that localities where this gas rises are unhealthy. Recent experiments show that the waters of some African rivers, whose mouths are remarkably unhealthy, contain this gas in considerable quantity. In this case the sulphuretted hydrogen arises from the mixture of the waters of the sea, which contain salts of sulphuric acid, with the river water which is charged with organic matter. This formation of sulphuretted hydrogen sometimes extends to a distance of twenty-seven miles from the mouths of the river. The water contains sometimes as much as six cubic inches of sulphuretted hydrogen in a gallon. The copper sheathing of ships is very rapidly corroded in this water, and the crews are attacked with malignant fevers.

Water at 64° dissolves 2½ volumes of sulphuretted hydrogen, and alcohol 6 volumes. These solutions soon become milky when exposed to air, the oxygen of which combines with the hydrogen of the gas and precipitates the sulphur. In the same way deposits of sulphur are formed in the neighborhood of mineral springs. In sulphurous acid and sulphuretted hydrogen oxygen and hydrogen are united to the same base, sulphur; when, therefore, these two gases

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* This gas is also found in foul sewers and putrid eggs, to which they, especially the latter, owe their peculiarly offensive smell. The water of sulphurous springs rarely contains more than one and one-half per cent of its volume of of this gas.

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other name is this acid called? Explain the first method for preparing hydrosulphuric acid—the second. Mention some of the properties of sulphuretted hydrogen. What are its relations to animal life? What is said of the waters of some African rivers? To what is the presence of sulphuretted hydrogen in these waters owing? How much hydrosulphuric acid does this water sometimes contain? What effect has it upon the copper sheathing of ships?—upon the health of their crews? What is said of the relations of hydrosulphuric acid to water?—to alcohol? Why do these solutions soon become milky? How do sulphurous acid and sulphuretted hydrogen decompose one another? How are brought together, they mutually decompose each other, the oxygen of the one taking the hydrogen of the other, and the sulphur of both being deposited. The vessel in which the two gases are mixed becomes coated with sulphur. In this experiment, the space between the tubes and the neck of the bottle in which the gases are mingled, should be stopped with loose cotton, or a tube open at both ends should pass through the cork, that there may be a free communication with the external air.

The disinfectants which are employed in places where this gas rises, operate by decomposing it.. Chlorine, iodine, and bromine, decompose it by uniting with its hydrogen, and depositing its sulphur. The oxygen of the air does the same to a small extent, as mentioned above.

A remarkable instance of an atmosphere fully charged with sulphuretted hydrogen being disinfected by hydrochloric acid gas, (p.104.) occurred in France in 1773. A cathedral atDijon, had become infected with putrid miasma from the bodies interred under the floor. Several unsuccessful attempts had been made to purify the air by explosions, aromatics, &c., until the building was finally deserted. Application having been made to Prof. Morveau, he took a glass vessel, supported by one of cast iron, and placed it on a few live coals in the middle of the church. He then put in six pounds of common salt, and two pounds of sulphuric acid, and hastily withdrew. The gas soon filled the vast space, and could be perceived even at the doors. At the end of twelve hours the church was thrown open and ventilated, when every disagreeable odor was found to be completely removed.

Sulphuretted hydrogen takes fire when a candle is immersed in it, but the candle is put out, and most burning bodies are extinguished by it. But when potassium is heated in this gas, it burns with great energy, and is converted into a sulphuret of potassium. The hydrogen that remains after the sulphur is in this manner withdrawn by potassium, is equal *in volume* to the original gas. Tin and many other metals, when heated in sulphuretted hydrogen, combine with its sulphur with flame. In all these cases the hydrogen liberated is equal to the *weight* of the sulphur which combines with the substances introduced into the gas; or, in other

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do the disinfectants which are employed in places where this gas rises act? In what manner was a cathedral at Dijon in France disinfected of putrid miasma? What is said of the relations of sulphuretted hydrogen to combustion? What substance burns in this gas with great energy? What other bodies burn words, when the gas is decomposed it is separated into equal weights of sulphur and hydrogen. For this reason its symbol is HS, or an equivalent of sulphur to one of hydrogen. Similar methods are often employed to determine the composition of other gases. Sulphuretted hydrogen burns with a beautiful pale blue flame, producing water and sulphurous acid, part of the sulphur being deposited. (73) Two volumes of sulphuretted hydrogen to three of oxygen form an explosive mixture. A little strong nitric acid thrown into a bottle of this gas occasions the immediate oxidation of its hydrogen, and often a slight explosion, when the escape of the vapor is impeded.

Sulphuretted hydrogen tarnishes certain metals, as gold, silver, and brass; hence utensils made of these metals should not be exposed to this gas. It also produces colored precipitates from many metallic solutions, and hence is constantly employed as a test in the laboratory. When diluted with 20,000 measures of pure hydrogen, it sensibly blackens a piece of paper which has been dipped in a solution of acetate of lead. (74) Letters formed with the nitrate or acetate of lead are invisible when the writing is dry, but are gradually brought out when the paper is held over a jar from which sulphuretted hydrogen is rising; the sulphuretted hydrogen takes the base, forming sulphuret of lead, and drives off or sets free the acetic acid, if acetate of lead was employed, or the nitric acid, if the solution was one of nitrate of lead. Solution of sulphuretted hydrogen in water is the most common form in which this is applied as a test. (75)

A bright surface of silver is a sure test for the presence of sulphuretted hydrogen, which is instantly tarnished by this gas, and a black sulphuret of silver formed on its surface. (76)

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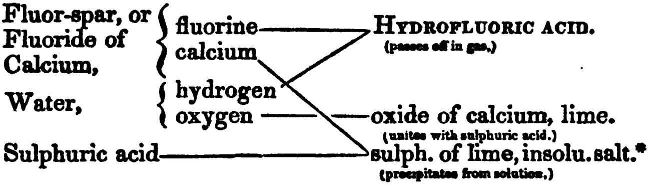
in sulphuretted hydrogen? Into what are they converted?—Ans.—Into sulphurets? How much hydrogen is liberated *in weight?* What therefore is the symbol of sulphuretted hydrogen? When potassium is burnt in sulphuretted hydrogen, how much hydrogen is liberated in volume? What is the color of the flame of sulphuretted hydrogen? What does it produce by its combustion? How is water formed in this combustion? Ans.—By the union of the oxygen of the air with the hydrogen of the sulphuretted hydrogen. How is the sulphurous acid formed? Ans.—By the union of the oxygen of the air with the sulphur of the sulphuretted hydrogen. What is the effect of sulphuretted hydrogen on certain metals?—on many metallic solutions? For what purpose is it employed in the laboratory? What illustration is given of the delicacy of this test? How may letters formed with the nitrate or acetate of lead be rendered visible? Why do these letters become black on holding them over a jet of sulphuretted hydrogen? What is the most common form in which the test with sulphuretted hydrogen is employed? What are some of the tests for the presence of sulphuretted hydrogen?

The most delicate test of the presence of sulphuretted hydrogen, when diffused in the air, is moist carbonate of lead spread on white paper.

	Hydrogen.	*Fluorine.*	*Symbol.*
HYDROFLUORIC ACID,	1·00	19·00	HF.

165. This acid is obtained by the decomposition of fluor-spar by strong sulphuric acid. This must be done in a retort of pure lead, silver, or platinum, and requires a gentle heat. The fluor-spar must be pure, and especially free from silica and the oxide of lead.


Fluor-spar, or Fluoride of Calcium,
fluorine
calcium
Water,
hydrogen
oxygen
Sulphuric acid
HYDROFLUORIC ACID.
(passes off in gas.)
oxide of calcium, lime.
(unites with sulphuric acid.)
sulph. of lime, insolu. salt.*
(precipitates from solution.)

Hydrofluoric acid at 32° is condensed into a colorless fluid, with a density of 1·069. In this state it can be preserved, even at a temperature above 32°, in well stopped bottles of silver or lead. Its avidity for water is extreme, and when brought into contact with it, the acid hisses like red-hot iron. It is the only liquid which dissolves, to any great extent, flint and glass. It cannot therefore be kept in glass vessels. It is often used to etch glass. For this purpose it is used in the laboratory for marking test bottles, and for designs on glass-plate, which are first traced through a coating of wax. The glass having been thus prepared, is placed over a vessel of lead in which there is an equal weight of fluor-spar and sulphuric acid. A gentle heat is applied to this vessel, and the hydrofluoric acid produced from this mixture will attack the glass in the lines which have been traced through the wax. The operation is completed in a few minutes, and the glass is then removed and cleaned by a little warm oil of turpentine. Liquid hydrofluoric acid may be employed for the same purpose, but the etching is not so

* This salt is very slightly soluble.

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165. Write the composition and symbol of hydrofluoric acid Explain the process by which it is obtained. Mention some of its properties ;—some of its uses. What is said of the action of hydrofluoric acid with some of the metals ?

distinct as when vapor is used, for, in this case, the figures are as transparent as the rest of the glass.(77)

Hydrofluoric acid possesses the acid properties in a very high degree. Its action on some of the metals is very powerful. With potassium it unites with explosion, evolving light and heat. It attacks and dissolves certain bodies which no other acid can affect, such as silicon, zirconium, and columbium, forming *fluates* of these substances, and setting free its own hydrogen. It is a most dangerous substance to experiment with, as it attacks all animal substances with wonderful energy. The smallest drop of the concentrated acid produces ulceration and death when applied to the tongue of a dog. Its vapor, floating in the air, is very corrosive, and should be carefully avoided. If it falls, even in small spray, on the skin of the hand or any other part of the body, it produces a malignant ulcer, which is very difficult to cure. Any considerable quantity of it would prove fatal. Its property of dissolving silica affords a method of analyzing siliceous minerals. It readily combines with the silica of these minerals, when in a state of fine powder, and still retains its elastic form, or passes off as hydrofluosilicic acid (p. 113).

	Silicon.	*Oxygen.*	*Symbol.*
SILICIC ACID,	22·18	24·00	SiO_3.

166. That which is commonly called flint, is in chemistry called silicic acid. We find it nearly pure in beryl, quartz, chalcedony, hornstone, jasper, rock-crystal, &c., which are

Fig. 55.*

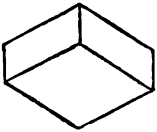


Fig. 56.†

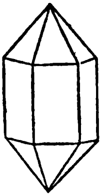


Fig. 57.‡

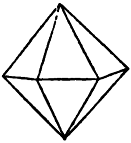
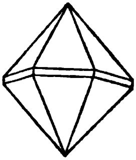


Fig. 58.||



* Obtuse rhombohedron.

† Six-sided prism, terminated by six-sided pyramids.

‡ Dodecahedron, or two six-sided pyramids joined base to base.

|| The two pyramids separated from each other by the intervention of a very short six-sided prism.

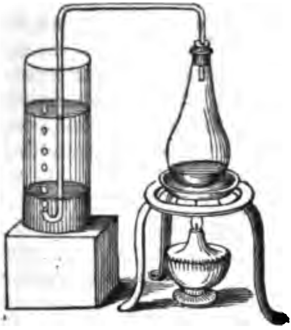
What is its effect on the animal system? Why may this gas be employed in the analysis of siliceous minerals?

but varieties of quartz. It is often beautifully crystallized in six-sided prisms and six-sided pyramids, and so transparent that ornamental stones are often made from them. The ornamental stones called Bohemian diamonds, are composed of quartz. Some of the forms of the crystals of quartz are represented in the preceding figures.

The red cornelian, the violet amethyst, the green jasper, the variegated agate and jasper, the opal and chalcedony, consist of silica; their colors are derived chiefly from metallic oxides.

167. Silica may be procured in sufficient purity for most purposes, by igniting specimens of rock-crystal, and throwing them while red hot into water, and then reducing them to powder. But to obtain this substance in a state of complete purity, a mixture of equal parts of fluor-spar and glass, both finely powdered, are put into a flask. (Fig. 59.) Upon this mixture, sulphuric acid is poured. A wide bent tube passes from the flask to the bottom of a glass jar, in which enough mercury is poured to cover the extremity of the tube. The jar is then about two-thirds filled with water, and heat applied to the flask. The first effect of the action of the sulphuric acid on fluor-spar is the disengagement of hydrofluoric acid (166.) This, however, being in contact with the powdered glass, is decomposed, and water and fluoride of silicon formed.

Fig. 59.



Hydrofluoric acid, { fluorine ——— FLUORIDE OF SILICON.
{ hydrogen [A gas. See next diagram.]
Silica (glass), { silicon
{ oxygen ——— water.*

* The water thus produced unites with a small portion of the fluoride of silicon, forming hydrofluosilicic acid, as in the next diagram, which passes over in vapor, and is condensed in the water of the jar, where also more of the same acid is formed, as is shown in diagram second.

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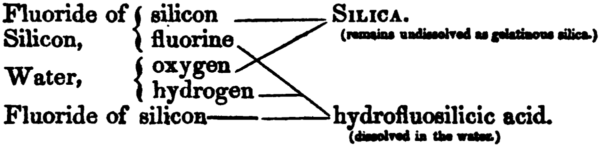
166. Write the composition and symbol of silicic acid. What are some of the sources of silicic acid?

167. How may silica be procured in sufficient purity for most purposes? Explain Fig. 59. How is fluoride of silicon obtained by the first diagram? How

The *fluoride of silicon* escapes through the tube, and rises from the mercury into the water above. As the bubbles come in contact with the water, they are decomposed; the fluoric acid unites with the water, and pure silica separates in the form of a beautiful gelatinous mass. This decomposition is represented by the following diagram:



The gelatinous silica may be removed from the water, and dried on a filter. A cloth filter is used for this purpose, and the silica, after being well washed on the filter* and dried, is heated to redness to expel the water. It is important in this experiment to keep the end of the tube so far beneath the surface of the mercury, that the bubbles of gas will not come in contact with the water until they have left the tube, otherwise the gelatinous silica formed at the mouth of the tube may entirely close it and prevent the passage of the gas.

168. Pure silica is a very fine, white, tasteless powder, which feels rough and dry to the touch and is gritty between the teeth. It is infusible, except by the most powerful heat of the oxy-hydrogen blowpipe, or by galvanism. In a state of fusion, it may be drawn out into threads, like glass. If dropped in this state into water, it solidifies to a transparent mass, free from flaws, and remarkably hard and tough, so that it sustains the blow of a hammer without breaking. The same effect is therefore produced as when red-hot steel is plunged into water. Though not itself volatile, yet when steam is passed into a mass of silica, heated above the melting point of cast iron, it is volatilized in large quantity, and deposited in the form of snow. Boracic acid (144.), volatilizes in a similar manner.

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* This process will be described in the latter part of the book.

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is silica obtained by the second diagram? In what state is this silica? Ans. —In the state of a gelatinous hydrate. How may the water be expelled from this hydrate?

168. What are some of the properties of silica? What is said of its solubility in water and dilute acids? Why does it not usually manifest its acid properties? How may these be developed? When are the salts of silica soluble? What silicates are insoluble?

Silica, unless recently precipitated, is not sensibly soluble in water and *dilute* acids. Although a very powerful acid, it does not usually manifest its acid properties on account of its insolubility. But when heated with the bases, especially with bases which are fusible, it unites with them and forms true salts (145.) When the proportion of base is considerable, the salts of silica are soluble, as the silicates of potash and soda, which are soluble in water. But where silicic acid is in excess, as in all the silicates which enter into the composition of glass, these silicates are insoluble. Under high degrees of pressure and temperature, or by slow action under ordinary pressure and temperature, a small portion of even these silicates is dissolved.

169. Silicic acid is nearly three times as heavy as water, its specific gravity being 2·66. In the arts, it is employed chiefly as a component of glass. Every kind of glass is a silicate, and all its varieties are produced by different proportions in the constituents employed, or by the impurity of the materials. Thus green bottle glass is made of impure river sand, and the most common kind of *kelp* or pearl ashes. The iron contained in the river sand, united with the impurities of the alkali, gives this kind of glass its color. Crown glass, for windows is made of a purer alkali and a sand which is free from iron. Plate glass for mirrors is composed of sand and alkali in their purest state, and, in the formation of flint glass, besides these pure ingredients, a considerable quantity of litharge, or red lead, is employed. The black oxide of manganese is also used to render glass colorless and to improve its transparency. The manganese not only becomes deoxidized itself, but also deoxidizes any oxide of iron, or other metallic oxide which may be present. (78)

170. Almost all springs, as well as plants, contain small quantities of silicic acid. If we evaporate spring water we find silica in the insoluble residue, and if we burn a plant, silica remains in the ashes. Grasses and different sorts of grain are particularly rich in silica, and, for this reason, have been called *siliceous plants*. Silica is to these plants, what bones are to men, the substance to which the stalks owe their firmness. If the soil is deficient in soluble silica, the stalk will be so weak as to bend over. The horse-tail plant

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169. What is the principal use of silica in the arts? To what are the different varieties of glass owing? What is the composition of green bottle glass?—crown glass?—plate glass?—flint glass? For what purpose is black oxide of manganese used in the manufacture of glass?

(Equisetum) contains so much silica that it may be used in polishing wood, horn, and some of the metals.(79) Many microscopic animals have siliceous coverings.

The siliceous minerals, such as rock-crystal, quartz, chalcedony, flint, &c., form a large part of the crust of the earth. Silica also predominates in the principal rocky masses of the globe.

171. The following table exhibits the composition, combining numbers, and symbols, of those elements, and their compounds which have now been described.*

SIMPLE ELEMENTS.

Organogens.			Pyrogens.			Halogens.		
Oxygen	O.	8.	Sulphur	S.	16.	Chlorine	Cl.	35.
Hydrogen	H.	1.	Selenium	Se.	40.	Iodine	I.	127.
Nitrogen	N.	14.	Phosphorus	P.	31.	Bromine	Br.	78.
Carbon	C.	6.				Fluorine	F.	19.

Hyalogens.		
Boron	B.	11.
Silicon	Si.	22.

ACID COMPOUNDS.

1. OXYGEN ACIDS.

Sulphur	S.	16	Sulphurous acid	SO_2. $16+16=32$.
Oxygen	O.	8	Sulphuric acid	SO_3. $16+24=40$.

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* This table shows the connection of all these bodies with each other, and serves also the very important purpose of a *review* of their composition, without which this would soon be forgotten, or retained so imperfectly as to be of no practical benefit.

170. Mention some of the sources of silicic acid. What purpose does silica serve in the stalks of grasses?

171. Write the composition and symbols of the organogens;—the pyrogens;—the halogens;—the hyalogens;—the acid compounds of sulphur and oxygen;—

Nitrogen	N.	14	Nitrous acid	NO_4. 14+32=46.
Oxygen	O.	8	Nitric acid	NO_5. 14+40=54.
Phosphorus	P.	31	Phosphorous acid	PO_3. 31+24=55.
Oxygen	O.	8	Phosphoric acid	PO_5. 31+40=71.
Carbon	C.	6	Carbonic acid	CO_2. 6+16=22.
Oxygen	O.	8		
Chlorine	Cl.	35	Chlorous acid	ClO_4. 35+32=67.
Oxygen	O.	8	Chloric acid	ClO_5. 35+40=75.
Silicon	Si.	22	Silicic acid	SiO_3. 22+24=46.
Oxygen	O.	8		

2. HYDROGEN ACIDS.

Chlorine	Cl.	35	Hydrochloric acid	HCl. 1+35=36.
Hydrogen	H.	1		
Sulphur	S.	16	Hydrosulphuric acid, or Sulphuretted Hydrogen	HS. 1+16=17.
Hydrogen	H.	1		
Fluorine	F.	19	Hydrofluoric acid, or Fluoride of hydrogen	HF. 1+19=20.
Hydrogen	H.	1		

172. This table is founded upon the tenth law of affinity (p. 63). This law is, "when a body, A, unites with other

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the acid compounds of nitrogen and oxygen; of phosphorus and oxygen;—carbon and oxygen;—chlorine and oxygen;—silicon and oxygen. What are these acid compounds called? Ans.—Oxygen acids. Write the composition and symbols of the hydrogen acids.

172. Upon what law of affinity is this table founded? State this law. How

bodies, B and C, the proportion in which A unites with B and C, will represent the proportion in which they will unite with each other." Thus in the above table let hydrogen be represented by A, and let the other bodies with which hydrogen unites, be represented by B, C, &c.; then the proportion in which hydrogen unites with these bodies, will represent the proportions in which they will unite with each other. Since A, or hydrogen, unites with B, or oxygen, in the proportion of 1 to 8 (forming water—see table,) and also with C, or sulphur, as 1 to 16 (forming sulphuretted hydrogen —see table,) therefore the compounds of sulphur and oxygen are as the numbers 16 and 8. Thus sulphurous acid $=SO_2=16+8\times2$. Sulphuric acid$=SO_3=16+8\times3$. Should any new compound of sulphur and oxygen be discovered, the proportion of these two elements will be expressed by some multiples of the numbers 16 and 8. If, therefore, any new compound should be sought for by experiment, the experiments would be in the following series, $16\times$(1, 2, 3, 4, &c.,) for the sulphur, and $8\times$(1, 2, 3, 4, &c.,) for the oxygen. Sometimes, however, what are called sesqui* compounds occur, a series of which ascend by the multiples ½, 1, 1½, 2, 2½, 3 &c.; thus A unites with ½, 1, 1½, 2, 2½, 3, proportions of B, or 2 A unites with 1, 2, 3, 4, 5, 6, B. The idea conveyed by the first proportion of *fractions* is not strictly correct, for the atoms of matter are indivisible. Half an atom of A cannot combine with an atom of B; by multiplying this proportion by 2, we obtain the second, in which the fractions are avoided; this, therefore, represents more correctly the method of combination among what are usually called sequi compounds.

The second part of the table gives the combining numbers of compound bodies. According to the eleventh law of affinity (p. 63.) the rule for compound bodies is, "*add together the numbers corresponding to the elements of the compound body; the sum will represent the proportion in which the compound enters into combination.*" Thus the combining number of sulphur is 16, that of oxygen 8, therefore that of sulphurous acid (SO_2) is $16+8\times2=32$, and that of sulphuric acid (SO_3) is $16+8\times3=40$.

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* Latin *sesqui*, one and a half.

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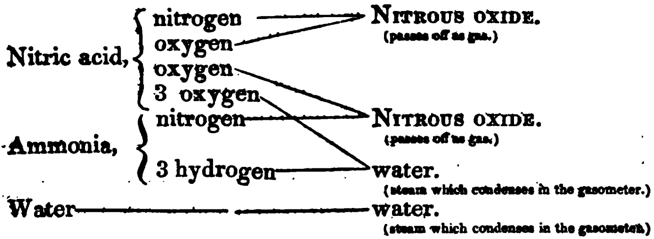
is this law illustrated? Why do the compounds of sulphur and oxygen unite with each other in the proportions represented by the numbers 16 and 8? In what series would any new compounds of sulphur and oxygen be sought for by experiment? What is meant by the term "sesqui compounds"? What is the true series by which this class of compounds are represented? Ans.—1, 2, 3, 4,

NEUTRAL COMPOUNDS OF NON-METALLIC ELEMENTS.

173. The neutral compounds of the non-metallic elements, or compounds which have neither acid or alkaline properties, are nitrous and nitric oxides, carbonic oxide, light carburetted hydrogen, olefiant gas, and phosphuretted hydrogen.

	Nitrogen.	*Oxygen.*	*Symbol.*
NITROUS OXIDE,	14·06	8	NO.
NITRIC OXIDE,	14·06	16	NO_2.

174. *Nitrous oxide, protoxide of nitrogen.* When nitrate of ammonia is exposed to a moderate heat, in a glass flask or retort, nitrous oxide is driven off and may be collected over *warm* water, or in water previously saturated with the same gas. The nitrate of ammonia should not fill more than a quarter of the retort as it is very apt to foam. Too much heat decomposes the nitrous oxide, and forms nitric oxide and nitrous acid. The nitrate of ammonia, which, by heat alone, gives off nitric oxide, is composed of nitric acid, ammonia, and water (of crystallization).



Nitrous oxide is a colorless gas with a faint and agreeable odor, and a sweet taste. It supports the combustion of a taper, or a piece of phosphorus, with almost as much energy as pure oxygen. It is, however, easily distinguished from oxygen by its solubility in cold water. It is absorbed by water in nearly equal volumes.(80) When a recently extinguished lamp with a red wick is introduced into it, the

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5, 6; of B, to 2, 4, 6, 8, 10, 12, of A. Upon what law of affinity, is the second part of the table founded? State this law. How is this law illustrated?

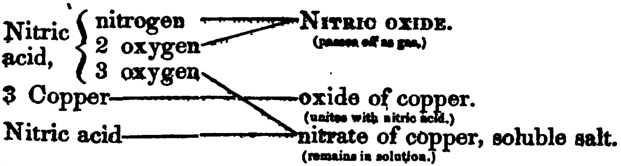
174. Write the composition and symbols of nitrous and nitric oxides. How is nitrous oxide prepared? Explain the diagram. Mention some of the properties of nitrous oxide. At what temperature does nitrous oxide become solid?

flame is instantly restored. Sulphur, when burning feebly, is extinguished, but when well ignited its flame is considerably enlarged.(81) When mixed with an equal volume of hydrogen, nitrous oxide may be exploded, liberating its own volume of nitrogen.(82)

By the pressure of 50 atmospheres, at 45°, nitrous oxide becomes a clear liquid, and, at 150° below zero, it freezes into a white snow-like mass. By the evaporation of this snow, a cold is produced, far below that produced by the evaporation of solid carbonic acid in a vacuum (p. 100,) or lower than 174° below zero. Solid nitrous oxide placed in the hand, by its sudden liquefaction and evaporation, produces intense cold, forming a blister on the hand like a burn. A single drop of liquid nitrous oxide also produces a wound like a burn. Metals dipped in this liquid produce a hissing sound, like that produced by plunging red hot iron into water. Ignited charcoal swims on its surface and burns with a vivid light, while sulphuric and nitric acids are immediately frozen by contact with it. Water freezes in contact with liquid nitrous oxide, but at the same time causes the evaporation of the nitrous oxide with a rapidity almost equal to explosion.

Nitrous oxide gas is more than once and a half heavier than air (sp. gr. 1·525.) The most remarkable effect of this gas is its intoxicating effect on the animal system. When inhaled it produces a strong propensity to laughter, a rapid flow of ideas, and an unusual disposition to muscular exertion. This state of excitement is not followed by depression as is the case where alcoholic stimulants are used. To some constitutions, however, this gas is injurious, producing when inhaled, giddiness, headache, faintness, and other disagreeable symptoms. An animal confined in this gas soon dies from the prolonged effects of the intoxication.

175. *Nitric oxide, deutoxide of nitrogen,* is formed by adding dilute nitric acid to copper clippings or turnings.



What degree of cold is obtained by the evaporation of solid nitrous oxide? What effect is produced by the evaporation of a small quantity of solid or liquid nitrous oxide upon the hand? What is the action of liquid nitric oxide on met-

Nitric oxide is a colorless gas. In contact with air, or oxygen gas, it produces deep red fumes of *hyponitrous acid* (p. 96.) This acid is formed when four measures of nitric oxide are mixed with one measure of oxygen, the gases being perfectly dry, and at a temperature of zero. It is a thin, mobile, colorless liquid, which becomes green at the ordinary temperature of the air.(83)

The property which nitric oxide possesses of forming red fumes of hyponitrous acid on contact with air, or oxygen, serves to distinguish it from all other gases, and is also a convenient test for free oxygen. Wherever oxygen is free or uncombined, it is at once detected on the addition of nitric oxide by the red fumes produced.

Cold water absorbs about three-fourths of its volume of nitric oxide, and acquires a sweetish taste. The strong affinity with which nitric oxide retains its own oxygen, and absorbs oxygen in a free state, renders its action unfavorable in most cases of combustion. Many bodies that will burn in nitrous oxide, which contains but one equivalent of oxygen (NO,) will not burn in nitric oxide, although this contains two equivalents of oxygen (NO_2.) Burning sulphur and a lighted candle are instantly extinguished by it, but phosphorus and charcoal, if in a state of vivid combustion when introduced into this gas, burn with increased brilliancy.(84) It is somewhat heavier than air (sp. gr. 1·525). With an equal bulk of hydrogen it forms a mixture that burns rapidly with a greenish-white flame. It cannot be breathed, as it produces a strong spasm whenever the attempt is made to inhale it.

	Carbon.	*Oxygen.*	*Symbol.*
CARBONIC OXIDE,	6.	8.	CO.

176. *Carbonic oxide* is prepared by mingling in a retort eight or ten parts of sulphuric acid with one part of dry, finely

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als?—on ignited charcoal?—on sulphuric and nitric acids?—on water? What is the specific gravity of nitrous oxide? What is its effect upon the system when inhaled?—on an animal confined in the gas?

175. How is nitric oxide formed? Explain the diagram. Mention some of the properties of nitric oxide. What are some of the properties of hyponitrous acid? What is its composition? (see p. 96.) How is nitric oxide distinguished from all other gases? In what way is nitric oxide a test for free oxygen? What other properties of nitric oxide are mentioned? What is its action on combustion? Why is it less favorable to combustion than nitrous oxide which contains only half as much oxygen? What bodies are extinguished by it? What substances burn with increased brilliancy in this gas? What is the specific gravity of nitric oxide? What is said of its mixture with hydrogen? Can nitric oxide be inhaled?

powdered, yellow prussiate of potash. By a gentle heat the salt is entirely decomposed, and the gas may be collected over water. It is a colorless, almost inodorous gas, burning with a beautiful blue flame, such as is often seen on a freshly fed coal fire. The carbonic acid, (CO_2) produced in the lower part of the fire, is converted into carbonic oxide (CO) as it passes through the red hot coals, which withdraw a portion of its oxygen. From the red hot coals it passes at a high temperature into the air, from which it immediately takes an equivalent of oxygen, burning with its blue flame and being converted into carbonic acid. It does not support the combustion of a candle.

Carbonic oxide, and carbonic acid, illustrate the fact, that bodies whose composition are very nearly alike, may be entirely different in properties. While carbonic acid is heavier than air (sp. gr. 1·524), carbonic oxide is lighter (sp. gr. 0·973). Carbonic acid is rapidly absorbed by water, carbonic oxide is not absorbed by pure water, or even by lime water. Carbonic acid does not burn, while carbonic oxide mixed with half its volume of oxygen explodes. It explodes also when mixed with nitric oxide. Carbonic oxide has no acid properties like carbonic acid.(85) It is much more poisonous than carbonic acid, producing a state of the system resembling apoplexy.(86) Small animals immersed in it die instantly.

	Carbon.	*Hydrogen.*	*Symbol.*
LIGHT CARBURETTED HYDROGEN,	6	2	CH_2.
HEAVY CARBURETTED HYDROGEN,	12	2	C_2H_2.

177. *Light carburetted hydrogen, fire damp,* is found abundantly in coal mines, being disengaged from the fresh cut surface of the coal, and from remarkable apertures called "blowers," which emit for a great length of time a copious stream or jet of gas. It is also found abundantly in stagnant pools during the decomposition of dead vegetable matter. From these places it may be obtained by stirring the mud at the bottom, and collecting the gas, as it escapes, by an inverted jar or other receiver. In this state it contains ten or twenty per cent. of carbonic acid, and a small portion of nitrogen. The carbonic acid may be removed by agita-

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176. How is carbonic oxide prepared? What are some of its properties? How is carbonic oxide formed in coal fires? What is its effect on the flame of a candle? In what respects do carbonic oxide and carbonic acid differ.

177. Write the composition and symbols of light and heavy carburetted hydrogen. Where is light carburetted hydrogen found? How may this gas be

ting it with lime water. It may be obtained also from a mixture of crystallized acetate of soda, four parts, solid hydrate of potash four parts, and powdered quicklime, six parts. When this mixture is strongly heated in a flask or retort, the gas is disengaged in great abundance, and may be received over water.

Light carburetted hydrogen is a colorless and nearly inodorous gas. It burns with a strong yellow flame, producing carbonic acid and water. It is not poisonous, and may be respired to a great extent without injury. All the value of the coal mines where this gas abounds, would have been lost, were it as poisonous as most of the gases. These vast deposits would also have been worthless, were this gas as *inflammable* as many of the other inflammable gases. By one property alone, in which the former differs from the latter, is the miner enabled to descend with safety into the mines. The latter, when mixed with air, may be exploded by an ignited surface, as a red hot iron, but the former mixed with air, can not be thus exploded. On this principle a lamp has been constructed, by which the miner can descend into the coal mines without any fear of producing an explosion by its flame. This lamp was invented by Sir Humphrey Davy, and called "*the safety lamp.*" The construction of this lamp will be described in the section on combustion and flame, as it depends on certain laws or properties of flame not yet explained. One volume of light carburetted hydrogen explodes when mixed with two of oxygen. One volume, with ten of common air, forms an explosive mixture. It detonates feebly when mixed with five or six times its volume of air. This small proportion, which is necessary to form an explosive mixture with air, accounts for the frequent and terrible accidents which occur in coal mines.

COMBUSTION AND FLAME.

178. *Nature and cause of combustion.* Three conditions are necessary in all cases of combustion: a supporter of combustion, a combustible body, and the requisite temperature, which is generally above the ordinary temperature.(87) Under these circumstances, combustion always takes place. In

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prepared? Mention some of its properties. In what proportions does light carburetted hydrogen form an explosive mixture with oxygen?—with common air?

178. What three conditious are necessary in all cases of combustion? How is this illustrated in the composition of gunpowder? Which one of the three conditions is wanting in the ordinary state of gunpowder? How is the tempera-

the composition of gunpowder, oxygen, (the supporter of combustion) is present in the saltpetre,* and carbon and sulphur (the combustibles) are also present. A red hot iron produces the requisite temperature in a portion of the powder, and the great volume of the flame, thus produced, elevates the temperature of all that it reaches, so that the whole mass explodes. In its ordinary state, gunpowder needs but one of the above mentioned conditions for its explosion—the requisite temperature. In its own composition it contains the combustible and the supporter of combustion. It will, therefore, explode *in any situation* where the requisite degree of heat can be in any way conveyed to it. In blasting rocks this temperature is produced by a small train of powder connected with the mass within the rock. For the same reason, if a gun barrel be filled with powder somewhat moistened, to diminish the rapidity of its combustion, and this moistened powder be set on fire at the end of the barrel, it will continue to burn, although the end of the barrel be stopped, as with a thick covering of cloth, or be plunged under water. In the latter case the gas, pouring forth in volumes from the powder burning within the gun-barrel, may be collected in jars above the water. The same experiment may be performed with a *fusee.* If the fusee be lighted at one end, it cannot be put out by placing weights upon it, nor by causing a length of it to pass under water. The fusee burns until it is entirely consumed, or the burning part is cut off from the rest. But apart from each other, the elements which form gunpowder will not explode, or even burn. Saltpetre may be melted and heated red hot by itself, without either explosion or combustion. Charcoal and sulphur may also in like manner be heated *by themselves*† without combustion; but, if the heated charcoal or sulphur be poured into red hot saltpetre, a vivid combustion will instantly take place with almost explosive energy.(88) In this manner the ancients formed what was called the *Greek fire.* Sulphur, resin, alcohol, camphor, and other combustibles, were melted with saltpetre, and in this melted mass cords were dipped and rolled up into balls. These balls being set

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* This may be seen by referring to saltpetre, the symbol of which shows a large amount of oxygen in its composition.

† To a moderate degree.

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ture required for the explosion of powder produced in blasting rocks?—in burning powder under water? Will the elements of gunpowder explode apart from each other? How may this be proved by experiment? In what manner was Greek fire formed? Why could not this fire be extinguished? Why does the addition on fire and thrown into the enemy's camp, could not be extinguished, for they contained in their own composition all the elements of combustion, and the energy with which they burned maintained constantly a very high temperature. When Constantinople was attacked in the reign of Leo, many of the ships of the besiegers were destroyed by this composition.(89) On the other hand, the absence or deficiency of either the supporter of combustion, the combustible body, or the requisite temperature, prevents combustion. Too much fuel put on a fire smothers it, because the air, the supporter of combustion, is shut out from the fire, or cannot act on the fire in sufficient quantity. If the fire is not replenished, it goes out, because the combustible has all been consumed, that is, it has all united with the oxygen of the air. In this case, the supporter of combustion may be obtained in inexhaustible quantity from the air, and therefore as long as the fuel is supplied, and the air allowed free access, the combustion will be maintained. When blown by the bellows, the fire burns with greater energy, because the oxygen of the air is brought more perfectly into contact with the fuel. For this reason, in wind furnaces, the fire is rendered intensely hot by the blast of air, the effect of which is more in proportion to *its velocity* than *its quantity*. The blast of air is increased in two ways, by increasing the *draught* of the chimney, and by bellows and blowing machines. The breathing of a multitude of persons in a building soon exhausts the air, to a great degree, of its oxygen. In such assemblies, therefore, the lights have sometimes been observed to burn very dim, owing to the great deficiency of oxygen, and the production of carbonic acid.

179. *Phenomena and cause of flame.* When the temperature of inflammable gases is raised very high, and in contact with the air, *they burst into a flame*. If previously mixed with a due proportion of oxygen, or of atmospheric air, they *explode*. In the first case, the supporter of combustion (oxygen of the air,) was entirely on the *surface* of the flame(90); in the second case, it was mixed in with the gas, and the combustion was therefore instantaneous and throughout its mass. Ordinary flame is produced by the contact of air

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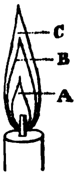
of too much fuel smother a fire? Why does the fire go out when not replenished? When blown by a bellows why does a fire burn with greater energy? Is the effect of a blast of air more in proportion to its quantity or its velocity? Why do lights sometimes burn dim in a crowded assembly?

179. Under what circumstances do gases burst into a flame? In what way are gases exploded? When are gases said to burn with a flame?—with explosion? Explain Fig. 60. Of what two gases is flame composed? Which pos-

with the surface of the ignited gas; hence, on the surface only does the combustion of ordinary flame take place. Flame is therefore hollow.(91) It presents a cone of gas (Fig. 60.) This cone consists of a dark central part, A, surrounded by a highly luminous cone or envelop, B, and on the outside a second cone, C, feebly illuminated. The flame may be considered as made up of two gases, carbon and hydrogen, of which hydrogen possesses far the greater attraction for oxygen. Therefore, at a little distance within the surface of the flame, the hydrogen takes all the oxygen, and the carbon, though intensely ignited by the flame of the hydrogen, is not burnt. This is the origin of the light, for the solid particles of carbon, when thus intensely ignited without the possibility of being burnt, give out great light. (92) This unburnt carbon of the inner flame collects at once on any solid substance placed over the flame. The mode of deposition may be best seen by drawing a piece of wire-gauze over the flame so as to reach to B.(93) In the exterior cone, C, these particles undergo combustion, and, in this state, produce less light than while intensely ignited in the inner flame.

Fig. 60.



180. That the light given out by flame is owing to the solid particles of ignited carbon, is evident from the fact that flames which contain the least carbon and the greatest amount of hydrogen give little light. Such is the flame of a spirit lamp. This, and the flame of pure hydrogen, give great heat but little light. Their great heat arises from the fact that little or none is expended in igniting carbon, and this absence of carbon accounts also for the little light which they give. If any solid matter, as magnesia or lime, be thrown into the flame of hydrogen, this flame instantly becomes more luminous. If a platinum wire be held in the same flame, it will become ignited and give out an intense white light. If, on the other hand, the solid carbon is burnt in such a manner as not to be intensely ignited, the flame gives out but little light. Thus if coal gas (185.) be min-

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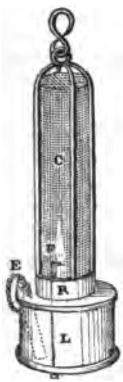
sesses the greater attraction for oxygen? In what state is the carbon within the flame? What then is the origin of the light of flame? How may the unburnt carbon be shown by experiment? What is said of the carbon in the exterior cone C?

180. What facts show that the light given out by flame is owing to the ignition of solid particles of carbon? What effect is produced by throwing solid matter in a state of minute division into a hydrogen or alcohol flame? What effect has a hydrogen flame on a platinum wire? Is the light of flame increased or diminished by burning more effectually the carbon? How is this shown in the case of coal gas?

gled with an equal bulk of air, the carbon burns more readily and becomes so feebly ignited that the gas loses half its illuminating power.

181. When flames are cooled they are at the same time extinguished; hence, when a piece of wire-gauze is held in a flame, the smoke will pass through, but become too much cooled to ignite above. When this smoke is heated by a second flame brought near to it, it takes fire and burns above the wire-gauze.(94) Upon this principle the *safety lamp*, (Fig. 61.) is constructed. C is a cylinder of wire-gauze, which terminates in a metallic ring, R. This ring screws on to the lamp, L. E is a tube extending nearly to the bottom of the lamp, that the end of this tube may be always covered with the oil of the lamp, and communication between the air within and without the lamp, in this way, prevented. Through this tube the lamp is filled with oil. At F, is seen the flame and a bent wire for trimming the wick.

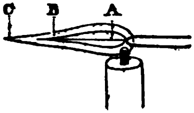
Fig. 61.



When this lamp is carried into an atmosphere charged with explosive gas, a blue flame is observed within the gauze cylinder from the combustion of the gas, and the flame in the center of the lamp may be extinguished. To provide against such cases, a coil of platinum wire is attached to the wick, which relights the lamp, when the miner speedily returns to better air. This coil remains ignited by the property which platinum wire possesses of decomposing oils, alcohol, &c., as will be explained hereafter.

182. *The blowpipe* is designed to concentrate the heat of flame on a small object by a current of air blown through the flame. The blowpipe flame, (Fig. 62.) is ignited *nearly throughout*, but different parts of the flame differ in their degree of ignition, and the extent to which the gas of the flame is consumed. Thus at the center of the flame, or A, the gas is perfectly consumed, as this is in the direct line of the air blown from the mouth. On the outside, or surface of the flame, the gas is also consumed, but between the outside and the center of the flame, there is a thin stratum which is unconsumed,

Fig. 62.



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181. What is the effect when the temperature of flame is lowered? By what experiment is this illustrated? Explain Fig. 61.

182. What is the object of the blowpipe? Explain Fig. 62. What portion

and which accumulates towards the extremity, in the space from B to C. This space, consequently, has a white color, and differs in chemical properties from the rest of the flame. At the point B, the gases are so hot that they have a powerful attraction for oxygen, which they consequently absorb from most substances that are placed in this part of the flame. This part is therefore called the *reducing flame*, as it reduces bodies from their oxides; for example, when the oxide of lead is exposed on charcoal to this part of the flame, pure lead is *reduced*, or obtained.

The outer portion of this flame is drawn out by the blast of air into a long cone, BC, the termination of which is of a blue color. In this part of the flame the gases are not so hot, and do not *surround the object* at the termination of the cone, at C. Hence, when a body is placed in this part of the flame, its oxygen is not taken away from it, but usually it acquires *more* from the atmosphere. This portion of the flame is therefore called the *oxidizing flame*. The hottest part of the blowpipe flame is a point between the outer and the inner flame.(95)

183. The *oxy-hydrogen blowpipe* is an instrument which produces the most intense heat by a flame of hydrogen and oxygen. These gases are kept in separate reservoirs but are made to unite by a *compound gas jet*. In Fig. 63, *c* and *e* are india-rubber tubes, connecting one with the hydrogen and the other with the oxygen gasometer. These are fastened to brass tubes provided with stop-cocks, *b* and *d*. These tubes unite in the compound jet, *a*. The construction of this jet is represented in Fig. 64. The central dot is the aperture at which the oxygen issues. To this aperture it is brought in the tube represented by the dotted line. Outside this tube, and between it and the tube marked *a*, the hydrogen passes and issues between the two tubes, and *around* the jet of oxygen. The gases therefore do not mingle until they leave the tubes and at the flame itself. There is, therefore, no danger of explosion, while the hydrogen, being supplied within by the oxygen from the gasometer, and without by the oxygen of the atmosphere, burns in a flame of great

Fig. 63.

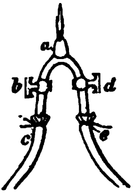
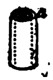


Fig. 64.



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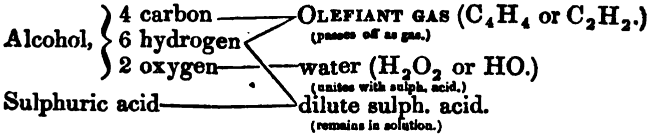
of the blowpipe flame is called the reducing flame? Why is it so called? What is meant by the oxidizing flame of the blowpipe? Why is this so called?

183. What is said of the oxy-hydrogen blowpipe? Explain Fig. 63.—Fig. 64. Why do not the mixed gases in this blowpipe explode? To what is the great

intensity. The quantity of the two gases can be easily regulated by the stop-cocks, *b* and *d* (Fig. 64.)

By the oxy-hydrogen blowpipe, substances perfectly infusible in a common furnace melt at once. Platinum melts like wax, and is even volatilized. By bringing the flame to bear on a cylinder of lime, a most intense light is produced. This is the principle of the Drummond light, as will be shown hereafter.

184. *Heavy carburetted hydrogen, olefiant gas.* This gas has twice as much carbon as light carburetted hydrogen (p. 121). It is prepared by mixing strong alcohol with five or six times its weight of sulphuric acid, in a capacious retort, and applying a gentle heat to the mixture. If too much heat is applied, the mixture foams up, and is apt to run out at the neck of the retort. Towards the latter part of the operation, carbonic and sulphurous acids are given off. The operation, therefore, should be discontinued after the gas ceases to come over freely.



Olefiant gas is colorless, tasteless, and inodorous. Water absorbs one eighth of its volume by standing. It burns with a splendid white flame.(96) It extinguishes a candle, for *neither* of its elements is a supporter of combustion. It is much heavier (sp. gr. 0·981) than light carburetted hydrogen (sp. gr. 0·559), but both these gases are lighter than air. A mixture of one part of olefiant gas with three parts of oxygen, when inflamed, explodes with a loud report. It also forms an explosive mixture with ten parts of common air.(97) Chlorine acts upon olefiant gas in a remarkable manner. When the two bodies are mixed, even in the dark, they combine in equal measure, and give rise to a heavy oily liquid of sweetish taste and ethereal odor, to which the name of chloride of hydrogen, or *Dutch liquid*, is given. It

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intensity of this flame owing? How may the proportion of either gas in the compound flame be regulated? Mention some of the effects produced by the oxy-hydrogen blowpipe.

184. How does the amount of carbon in olefiant gas compare with that in light carburetted hydrogen? State the process for preparing olefiant gas and explain the diagram. What are some of the properties of olefiant gas? Why does

is from the formation of this oily substance by the mixture of two gases, that the term *olefiant,* (oil making,) is derived. When mixed with twice its volume of chlorine in a tall jar, and lighted on the top, it burns with a splendid red flame, leaving a dense deposit of carbon on the interior of the jar. In this experiment, the chlorine and hydrogen unite, forming hydrochloric acid, and the carbon is set free. Olefiant gas is decomposed by being passed through a tube heated to bright redness. If the temperature is very high, a deposit of charcoal is produced, and light carburetted hydrogen, or even free hydrogen, given off.

Olefiant gas is given off naturally in great abundance at several places. A natural supply of this gas, mixed with light carburetted hydrogen, is used to light the city of Fredonia, N. Y. It also occurs at Salina, and at Niagara, at the edge of the river above the rapids. At some of the salt works at Kenawha, Va., the kettles for evaporating the salt are heated by conducting the burning gas under them. Vast quantities of this gas are given off from the Artesian borings in those regions.(98)

The gas used in lighting cities, owes its illuminating power to the amount of olefiant gas which it contains. Explosions often occur from the gas becoming mingled with the air of the house, by escaping from the jet. Only one-tenth part of the gas is required to render the air explosive. The gas for lighting cities is usually made from coal. Were it not for its greater cost, *oil gas* would be much preferred to that made from coal, for it possesses far higher illuminating power. It is made by dropping oil into a red hot iron retort, filled with coke, which exposes a large ignited surface to the oil. Illuminating gas may also be produced abundantly from cotton seed, and of a finer quality than that from either coal or oil, a process first discovered and described by Professor Olmsted.*

185. *Coal gas.* In Fig. 65, some of the principal arrangements used in the gas works are represented. *a, a, a,*

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*American Journal of Science, Vols. VIII and IX.

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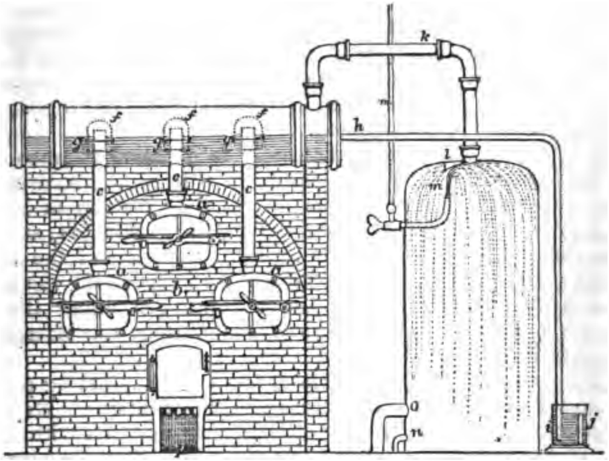
this gas extinguish combustion? What is said of the specific gravity of this gas and light carburetted hydrogen? With what proportion of oxygen does it form an explosive mixture? What are the proportions for an explosive mixture with common air? What is said of the action of chlorine on olefiant gas? Whence is the name olefiant derived? How may this gas be decomposed? Which of the components is deposited? Which is given off? Mention some of the places where olefiant gas occurs naturally and in great abundance. To what does the gas used in lighting cities owe its illuminating power? Of what is this gas usually made? Why is not oil gas used? From what other source may gas be produced?

are three retorts which project out from the brick work, *b*, to a distance sufficient to allow the pipes, *c*, *c*, *c*, to pass outside of the furnace. These pipes pass from the retort into a large pipe called the *hydraulic main*. They enter through a stratum of condensed tar and water, which covers the bottom of the hydraulic main, and terminate in *thimbles*, *f*, *f*, *f*, which are supported above the pipes by bolts, *g*, *g*, *g*. A small pipe, *h*, carries off the excess of tar and water, which condenses in the hydraulic main. This pipe descends into the short cylinder, *i*, into which, consequently, the excess of tar and water is emptied. When the cylinder is filled to the level of the pipe, *j*, the tar and water flow off through this pipe into the *tar well*, which is not represented in the figure.

Fig. 65.



The gas rises through the pipes, *c*, *c*, *c*, passing through the thimbles, *f*, *f*, *f*, beneath the stratum of tar and water, and *bubbles up* into the space above. From the hydraulic main it passes through the pipe, *k*, and descends into the large cylinder, *l*. In this cylinder it meets with a very small stream of water, *m*, which is brought through the pipe, *m*, *m*, from a reservoir of water, at an elevation of fifteen or twenty feet above the cylinder, *l*, and consequently issues

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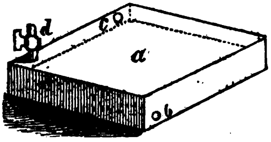
185. Explain Fig. 65. Which of the impurities of the gas are first removed? How is this effected? What is the object of the thimbles *f*, *f*, *f*? What impurity is removed from the gas in cylinder *l*? How is this accomplished?

with great force. Striking on a projection within the cylinder, this stream is dissipated in spray immediately in front of the stream of gas. The object of this arrangement will be explained below. The water from this spray collects on the lower part of the cylinder, and passes off through the pipe *n*. The gas is carried off in the pipe *o*.

The retorts, *a*, *a*, *a*, are opened, and coal(98) thrown in rapidly. To this, in some cases, a single shovel-full of rosin is added. The doors of the retorts are then closed and screwed up, so as to be air tight.(99) The gas is driven off by the heat of the fire, beneath the retorts. In this state it is so impure, as to be unfit for the purposes of illumination. The first object, therefore, is to remove these impurities. By a diminution of temperature, as the gas passes through the pipes, *c*, *c*, *c*, and into the hydraulic main, most of the *coal tar* and *watery vapor* is condensed. The remainder is afterwards condensed in the pipes and cylinders, through which the gas passes. The object of the thimbles, *f*, *f*, *f*, is to *break the connection between the pipes*, *c*, *c*, *c*, or between the retorts, *a*, *a*, *a*. By this arrangement, when one of these retorts is opened, the gas from the other retorts, and the hydraulic main, cannot descend through the pipe, *c*, and escape into the air.

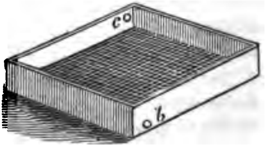
When the tar and watery vapor are condensed, the next object is to absorb the ammonia, which is another impurity of the gas. This is done by the small jet of water in the cylinder, *l*. The very fine spray into which this jet is dissipated, brings the water and the gas into perfect contact, and produces a complete absorption of the ammonia.

Fig. 66.



The remaining impurities of the gas are, chiefly, sulphuretted hydrogen and carbonic acid. To remove these, a box, *a*, (Fig. 66.) containing slaked lime is employed. The construction of this box is seen in Fig. 67. The gas enters at *b*, *beneath* a frame work of wire-gauze. The slaked lime is placed upon this wire-gauze, through which the gas passes and

Fig. 67.



Explain Fig. 66.—Fig. 67. How is the purity of the gas after passing through the lime boxes determined? To what does the gas pass from these boxes? Explain the *principle* of the gasometer;—its construction. For what purpose is waleaves the box at *c*. By passing through the apertures of the wire-gauze, the gas is brought into perfect contact with the lime. It is necessary that the gas should pass through *three* of these boxes, before it is sufficiently pure for use. The degree of its purity, is determined by *test-papers*, which are prepared with acetate of lead. One of these test-papers is held over the stop-cock, *d*, (Fig. 66.) which is then opened, and a stream of gas let out on the paper. If sulphuretted hydrogen be present, it immediately blackens the paper, by the formation of sulphuret of lead. This effect is instantaneously produced by the gas from the first box, after sometime by that from the second, and not at all by that from the third.

The gas being purified, passes from the lime-box through the pipe, *c*, (Fig. 67,) to the *gasometer*. This is a large reservoir of peculiar construction, designed to receive all the gas which is made, both during the day and night, and to distribute this by the pressure of its weight, through the pipes of the city. The general principle of its construction may be illustrated in the following way—

If a receiver, like one of those represented in Fig. 35, page 67, be filled with water, it will sink beneath the surface, and may there be inverted. It now stands entirely beneath the surface of the water, and rests upon the bottom of the pneumatic trough. Underneath the receiver introduce a bent tube, and force a small portion of air within. This will rise, and, if in sufficient quantity, it will buoy up the receiver so that it will float in the water.

The gasometer may be considered as an immense receiver. A pipe from the gas-works introduces gas from beneath, and the cylinder is buoyed up from the water by which it is surrounded, and with which it is at first filled. This cylinder is surrounded by another which holds the water, and between the outer and the inner cylinder, wheels are placed by which the rise and fall of the inner cylinder is effected with less friction. A *mast* also runs up from the center, which serves to steady the inner cylinder against winds, and other causes of agitation. From the gasometer the gas passes off in a large pipe to the city.

In the general description given above, several facts have been omitted. Some of these may now be mentioned; especially those which illustrate chemical principles.

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ter kept in the iron trough beneath the fire? How does the vapor of water increase the energy of the fire? What is the fuel employed in gas-works? How

In Fig. 65, p. 130, is seen an iron trough *p*, which is kept constantly full of water. The vapor of this water rising through the fire, is decomposed, its hydrogen is burnt, and thus affords a volume of flame which plays about the retorts, and greatly increases the effect of the fire. The oxygen of the water also increases the intensity of the combustion. Water is used with the same kind of coal, and for a similar purpose, in the blacksmith's forge.

The fuel employed is coke. This is made in the retorts, and is what remains from the coal after the gas is driven off. When drawn out of the retorts, the coke is in an ignited state. It is therefore received into iron waggons, and drawn without the building, where it is extinguished with water. By this process it absorbs a great deal of water, and this, as well as that which rises in vapor from the iron trough beneath the fire, is an important part of the fuel. In this way, the coke produced is usually found more than sufficient for the supply of the fire. The excess is sold, and is, therefore, one of the items of profit in gas works. The coal-tar is also sold, and has of late come to be in demand as an article of fuel in glass works, being used instead of rosin, which has been hitherto employed, to increase the intensity of their fires. The lime from the boxes, (Fig. 67,) being charged with carbonic acid and sulphuretted hydrogen, is valuable for manure. The ammoniacal liquor produced in cylinder *l*, (Fig. 65,) is sometimes used for the same purpose.

	Phosphorus.	*Hydrogen.*	*Symbol.*
PHOSPHURETTED HYDROGEN,	31	3	PH_3.

186. Phosphuretted hydrogen is formed, when the phosphuret of calcium is acted on by water. For this purpose, fill a small retort with water, *entirely full*, and, through the top or neck of the retort, drop a few pieces of the phosphuret of calcium. These will sink to the bottom of the retort, and a stream of gas will rise to the top and inflame on coming in contact with the air. The neck of the retort is now closed with the stopper, and the gas, gradually increasing in amount, at length fills the retort and excludes the water, and finally issues from the retort, and rises above the water in bubbles, that inflame on coming in contact with the air.

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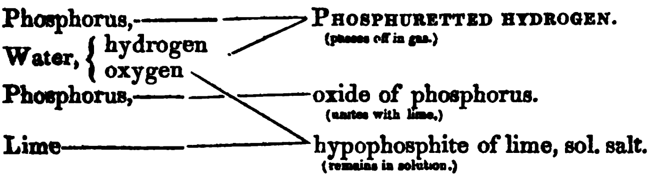
is this obtained? What is done with the excess of coke?—the coal-tar?—refuse lime?—ammoniacal liquor?

186. Write the composition and symbol of phosphuretted hydrogen. State the method of preparing this gas;—the second method. Explain the diagram.

The gas may be collected in jars, by the displacement of water.

Phosphuretted hydrogen may also be made by filling a small retort with water, containing quicklime recently slaked. Into the retort thus prepared, drop a few pieces of phosphorus, and apply a gentle heat. The gas will gradually accumulate, as in the last process, and drive out the lime-water; it will then issue from the retort in bubbles, which are spontaneously inflammable.



If a small jar of phosphuretted hydrogen be collected, and inverted in contact with the air, it will burn with a beautiful white flame. When kept over water for some time, it loses this property, without undergoing any appreciable change. Charcoal, and other porous absorbents, also destroy the spontaneous inflammability of this gas, and the same effect is produced by a minute quantity of several combustible bodies, as the vapor of potassium, ether, or essential oil. It detonates with oxygen, combining with half its volume of this gas. Only *one bubble* of either of these gases should be let up into a jar of the other at a time, as a much larger quantity would produce a violent explosion. Phosphuretted hydrogen also explodes with chlorine, giving a brilliant greenish-white light. With nitrous oxide gas, it detonates by the electric spark. It is somewhat heavier than air (sp. gr. 1·24.) Its odor is very disagreeable, resembling the smell of fish in a state of decomposition, which is owing to the formation of this gas.

Phosphuretted hydrogen may be prepared in such a manner as not to be spontaneously inflammable. It exists, therefore, in two *allotropic* states, as a spontaneously inflammable gas, and a gas not spontaneously inflammable.

Phosphuretted hydrogen decomposes some metallic solu-

What is the most remarkable property of phosphuretted hydrogen? How may its spontaneous inflammability be destroyed? In what proportions does it detonate with oxygen? With what other gas does phosphuretted hydrogen explode? How may it be exploded with nitrous oxide gas? What other properties of phosphuretted hydrogen are mentioned?

tions, as those of copper and mercury, and forms metallic phosphides. When pure, it is entirely absorbed by sulphate of copper and by chloride of lime.

187. The following table exhibits the composition, symbols, and combining numbers of the neutral compounds of the non-metallic elements.

NEUTRAL COMPOUNDS.

1. OXYGEN COMPOUNDS.

Nitrogen Oxygen	Nitrous oxide	NO. $14+8=22$.
	Nitric oxide	NO_2. $14+16=30$.
Carbon Oxygen	Carbonic oxide	CO. $6+8=14$.

2. HYDROGEN COMPOUNDS.

Carbon Hydrogen	Light carburetted hydrogen	CH_2. $6+2=8$.
	Heavy carburetted hydrogen	C_2H_2. $12+2=14$.
Phosphorus Hydrogen	Phosphuretted hydrogen	PH_3. $31+3=34$.

ALKALINE COMPOUND OF NON-METALLIC ELEMENTS.

	Nitrogen.	*Hydrogen.*	*Symbol.*
AMMONIA,	14	3	NH_3.

188. *Ammonia* is the only alkaline compound of the non-metallic elements. It is prepared from equal parts of

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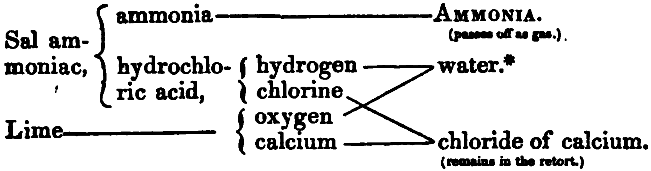
187. Write the composition, symbols, and combining numbers of the neutral oxygen compounds of the non-metallic elements ;—the hydrogen compounds.

muriate of ammonia, or sal ammoniac, and freshly slaked dry lime. These are mingled and heated in a glass or iron vessel; in the latter, when the quantity of the mixture is considerable. It may be collected by inverting a jar over the end of the tube from which the gas issues. Being lighter than air, it will displace it (100), and fill the inverted jar. It may also be collected over mercury.



Ammonia is a colorless gas, with a pungent, exciting, and enlivening odor. By its caustic properties it acts powerfully on the eyes and nose. It cannot be breathed in its pure form; but, when diluted with air, it may be taken into the lungs with safety. It does not take fire with the flame of a candle, nor does it support combustion. The flame is, however, considerably enlarged, and is tinged with a pale yellow color when immersed in the gas. A small jet of ammonia burns in oxygen, and, in about equal volumes,† it forms with oxygen an explosive mixture. With iodine, ammonia forms an explosive compound, called the *iodide of nitrogen.* It is prepared by dropping a few grains of iodine into a phial of dry ammoniacal gas. The iodine is agitated in contact with the gas, and it becomes gradually changed to a viscid brown substance, which is a compound of iodine and the nitrogen of the ammonia. This substance is exploded by the warmth of the hand with great violence.

Like the compounds of carbon and hydrogen, this gas is lighter than air. The specific gravities of these three gases are, 0·559 (light carburetted hydrogen), 0·589 (ammonia), 0·981 (olefiant gas).

Ammoniacal gas may be separated into its elements by

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* Passes off in vapor, which, as it condenses, absorbs a small quantity of the ammonia.

† Four of ammonia to three of oxygen.

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188. What is the only alkaline compound of the non-metallic elements? Write the composition and symbol of ammonia. State the process for preparing ammonia. Explain the diagram. Mention some of the properties of ammonia. In what way may ammoniacal gas be separated into its elements? At what temperature and pressure does it become a liquid? To what extent is

passing electrical sparks through it for a considerable time. Under a pressure of 6½ atmospheres, at 50°, it becomes a transparent, colorless liquid. This gas is absorbed by charcoal to the extent of 90 times it volume.(101)

Water dissolves about 7000 times its volume of ammoniacal gas, forming a solution which is known by the name of *liquor ammoniæ*.(102) By heat, the greater part of the gas can be again expelled. The concentrated solution is a clear, colorless liquid. Its density is nearly that of water, (sp. gr. 0.875.) It possesses the odor, taste, and other properties of the gas itself. It is not corrosive, but tastes highly alkaline. When cooled slowly to—40°, it crystalizes in long needles of a silky lustre. On account of its great volatility, it must be kept in well stopped bottles. Alcohol also dissolves ammonia in large quantity.

Ammonia *in a free state*, is known in three ways, by its odor, by its action on vegetable infusions, or reddened litmus paper(103), and especially by the white cloud formed on bringing to it a rod moistened with hydrochloric acid.(104) In any of its salts it can also be detected by being heated with hydrate of lime, or solution of caustic potash or soda, by which these salts are decomposed, and ammonia evolved in a free state.(105)

Ammonia is given off in vast quantities in the decomposition of animal and vegetable substances. Its salts form excellent manure for soils. They are the principal ingredient in many kinds of manure, and, therefore, the escape of ammonia from manure heaps, should be prevented by sprinkling them from time to time, with diluted sulphuric acid, or by strewing gypsum over them. These substances form with the ammonia, sulphate of ammonia, a salt which does not volatilize at common temperatures, and which is beneficial to the soil, both from its ammonia and its sulphuric acid. Moist, absorbent earth answers the same purpose to some extent.

Ammonia exists also, combined with acids, in some of the saline products of volcanoes, and, in very small quantities, it may be detected in sea-water. It exists in small quantity in the air, especially in towns where bituminous coal is burned to a great extent, and in large cities. Small stel-

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ammonia absorbed by charcoal?—by water? What is its solution in water called? Mention some of the properties of this solution. In what three ways is free ammonia detected? How may it be detected in its salts? What are some of the sources of ammonia? In what way may the escape of ammonia from manure heaps be prevented? What is the action of sulphuric acid or lated crystals of the sulphate of ammonia are sometimes observed on the windows of these cities.

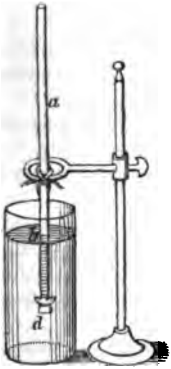
The composition, symbol, and combining number of this alkaline compound are

$$\left.\begin{array}{l}\text{Nitrogen}\\ \text{Hydrogen}\end{array}\right\}\text{Ammonia}\quad \begin{array}{l}NH_3.\\ 14+3=17.\end{array}$$

ENDOSMOSE, EXOSMOSE, DIFFUSION OF GASES.

189. A glass tube, *a*, (Fig. 68.) is closed at the bottom by a diaphragm, *d*, (a piece of bladder, india rubber, &c.) and filled with a liquid to *b*. It is then placed in the vessel, *b d*, which contains a liquid different from that which the tube contains. Both liquids being at the same level, at *b*, the tube is allowed to remain for a time, when it is found that *both* liquids pass through the diaphragm at the bottom of the tube, but that *this exchange takes place unequally*, so that the volume of one of the liquids increases, while that of the other diminishes. The stronger current, whether this comes from the liquid of the tube to that of the glass, or in the contrary direction, is called *endosmose*, the weaker, *exosmose*. Sometimes the two currents are of the same strength, so that the level in both the tube and the glass remains unaltered.

Fig. 68.



190. Endosmose and exosmose take place, not merely through an animal membrane, but also through baked, but unglazed or porous earthen-ware, through the stems of plants, and through a great number of other substances. When an india-rubber bottle is filled with ether, and placed in alcohol, the endosmose or stronger current is from the ether to the alcohol, and the bottle thus empties itself. If, on the other hand, the bottle is filled with alcohol and placed in ether, the endosmose of the ether distends the bottle, by augmenting the *volume* of the alcohol. At the same time,

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gypsum in this case? Where is ammonia found combined with acids? Write the composition, symbol, and combining number of ammonia.

189. Explain Fig. 69. What is meant by endosmose?—exosmose?

190. Through what substances does endosmose take place? Mention some examples of endosmose through india-rubber. When ether, alcohol, and water, are compared, in what way does endosmose take place through india-rubber?

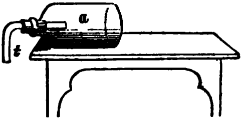
exosmose takes place, or the alcohol passes out of the bottle into the ether, but the current in this direction is much weaker. If the bottle is filled with ether and placed in water, the ether passes into the water, and the contents of the bottle diminish. If filled with alcohol, the same effect takes place, though, as mentioned above, the bottle thus filled, distends in ether. If water be used to fill the bottle, it will distend in either alcohol or ether. Endosmose, through *india-rubber* is, therefore, from ether to alcohol or water, and from alcohol to water.

191. If a *bladder* be tied over a glass filled with alcohol, and the glass be inverted under water, the endosmose of the water to the alcohol is so powerful, that the bladder swells up, and when pricked with a needle, the alcohol spirts out in a long stream. In this case the endosmose is opposite to what it was in the last, being from the water to the alcohol, while with india-rubber, it was from alcohol to water. The same change of endosmose, occurs between water and ether.

192. Endosmose is directed from water to solutions of glue, gum, sugar, and white of egg; the rise of these liquids in the tube, *d*, (Fig. 68,) when they have the same density with each other, is as the numbers, 3, 5, 11, 12, the first number, or 3, representing the rise of the solution of glue, the second number, or 5, that of gum, the third number, or 11, that of sugar, and the number 12, that of the white of egg; the last, therefore, causes the greatest endosmose from water.

193. *Diffusion of gases.* This principle has already been mentioned and partially described, (111.) It is not, however, confined to the gases which make up the atmosphere, but is a property of all gases. Though many of the gases differ from each other very greatly in their specific gravities, yet they diffuse themselves through one another, and form a uniform mixture. A bottle, *a*, (Fig. 69.) is provided with a bent tube, *t*, and laid horizontally upon a table. Different gases are introduced within this bottle, and it is so placed that the tube, *t*, shall be turned downwards, if the gas is *lighter* than the air, and upwards if the gas is *heavier* than the air. The

Fig. 69.



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191. In what way does endosmose take place through bladder?
192. To what solutions is endosmose directed from water?
193. Is diffusion a property of all gases? Explain Fig. 70. Which gases

gas is found to escape from the bottle *contrary to its specific gravity*, and its place becomes supplied with air. The comparative rapidity with which this takes place in the different gases, may be seen from the following table:

Of 100 volumes of gas there disappeared—

	Sp. gr.	In 4 hours.	In 10 hours.
Hydrogen	1	81·6	94·5
Light carb. hyd.	8	43·4	62·7
Ammonia	8·5	41·4	59·6
Olefiant gas	14	34·9	48·3
Carbonic acid	22	31·6	47·0
Sulphurous acid	32	27·6	46·0
Chlorine	35·4	23·7	39·0

From this table it appears that gases escape the more rapidly the lighter they are, and their *power of diffusion* probably varies in the inverse ratio of the square roots of their specific gravities. Thus 47 measures of hydrogen escaped in two hours, and the same volume of carbonic acid in ten. Now this proportion of 10 : 2, or 1 : 5, is nearly that of the square root of 1 (sp. gr. of hyd.) to the square root of 22, (sp. gr. of carb. acid.)

194. If the bottle contains a *mixture* of two gases, the more diffusible of the two will escape in greater proportion into the air, and the less diffusible in smaller proportion, than if each gas were contained alone in the bottle. This will take place, although the bottle be so placed that gravity will favor the less diffusible, and oppose the more diffusible gas, as when hydrogen and carbonic acid are mixed, and the bottle containing the mixture is so placed that the tube opens downwards. In this case, the hydrogen will escape in greater proportion than the carbonic acid, and more rapidly than it would if the carbonic acid were not present, while the latter will escape less rapidly, on account of the presence of hydrogen. In the same manner, if two flasks are connected by a tube, as represented on page 72,* and the upper flask is filled with *equal measures* of hydrogen, (sp. gr. 1,) and olefiant gas, (sp. gr. 14,) and the lower with carbonic acid, the upper flask will, after ten hours, be found

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* The lower flask in this case should be seven times larger than the upper.

have the greatest power of diffusion? By what rule may this power be determined? How is this illustrated?

194. What effect has mixture on the diffusion of gases? How is this illustrated?

to contain only $\frac{1}{4}$ as much hydrogen by volume, as the olefiant gas. Though the volumes of the hydrogen, and the olefiant gas were at first equal, and though hydrogen is 14 times lighter than olefiant gas, it has descended into the lower flask 4 times as rapidly as the olefiant gas, while carbonic acid, the specific gravity of which is 22, and which is therefore heavier than either gas in the upper flask, has risen to supply the place of a portion of both these gases.

195. Mixture of gases likewise takes place when they are separated by a *porous body*, or by a *cracked glass vessel.* Hydrogen kept in a cracked receiver, standing over water, escapes by degrees through the crack into the surrounding air, and the water in the receiver rises to the height of 2$\frac{2}{3}$ inches above the outer level. With the hydrogen which has not escaped, but still remains in the receiver, 7 per cent. of nitrogen is found, which has entered by exosmose from the external air. The exosmose, in this case, is confined to the nitrogen of the external air, for no oxygen is found within the receiver. In the same manner hydrogen escapes out of bottles closed even with well ground stoppers, if the stoppers are not greased. If the cracked receiver, containing hydrogen, be placed over a trough of mercury, and covered with an uncracked receiver, containing carbonic acid, or air, the mercury will rise in the inner receiver to the height of an inch or two, and sink in the same proportion in the outer. This difference would be still greater, but, when it amounts to about two inches, the *pressure*, or weight, of the mercury in the inner receiver, draws the air, or carbonic acid, from the outer receiver, through the crack, thus compensating *in volume* for the hydrogen which has escaped. If the experiment be reversed, and the cracked receiver be filled with air, and the outer receiver with hydrogen, the mercury will rise in the outer and sink in the inner, proving that the hydrogen makes its way downwards through the inner and cracked receiver, contrary to its specific gravity.

196. If a sheet of india-rubber be tied over the opening of a wide-mouthed bottle full of hydrogen gas, it is soon pressed *inwards*, even to bursting. If the bottle be filled

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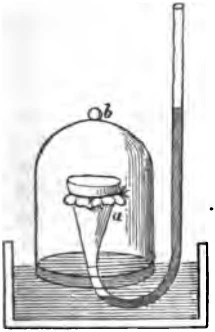
195. Under what other circumstances does the mixture of gases take place? By what facts is this shown? When the cracked receiver contains hydrogen and is surrounded by a receiver containing carbonic acid over mercury, what action is observed? What is the action when the experiment is reversed, or when the outer receiver contains hydrogen and the inner and cracked receiver contains carbonic acid?

with air, and placed in an atmosphere of hydrogen, the swelling and bursting take place *outwards*. A well closed bottle of india-rubber, if perfectly empty, does not distend when placed in hydrogen gas; but if it contains a small quantity of air, distention takes place. Almost all other gases, except nitrogen, exhibit the same relations towards common air as hydrogen does, but in different degrees. To measure their various powers of diffusion, an apparatus, like that represented in Fig. 70, is employed. A siphon tube, *a*, is funnel-shaped at the shorter arm. A sheet of india-rubber is tied over this arm, and the other arm is made very long. Mercury is poured into the longer arm, so that it rises in the shorter arm, and encloses a portion of air beneath the india-rubber. The shorter arm is then introduced under a receiver, *b*, standing over mercury, and filled with the gas to be examined. This gas penetrates the india-rubber, mixes with the air beneath, and, increasing its volume, causes the mercury to rise in the longer arm, sometimes to the height of 63 inches, or more than twice its usual height in the barometer. It might be driven higher if the india-rubber could sustain a greater pressure without bursting. By experiments of this kind on different gases, it is found that the same volume of ammonia passes through the india-rubber to the air beneath in 1 minute, as of sulphuretted hydrogen in 2½, of carbonic acid in 5½, of hydrogen in 37½, of oxygen in an hour and 53 minutes. Some of these gases are absorbed by the india-rubber, causing it to swell up. Of carbonic acid it absorbs an equal volume.

Fig. 70.



197. A moist bladder, or moistened gold beaters' skin, acts like a sheet of india-rubber. A moist bladder, two-thirds filled with coal gas, or air, swells when suspended in carbonic acid gas, and finally bursts. In this experiment as much as 40 per cent. of carbonic acid sometimes mixes with the coal gas, while only a very small quantity of the

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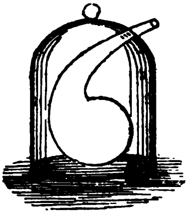
196. When a sheet of india-rubber is tied over the opening of a wide-mouthed bottle full of hydrogen gas, the bottle standing in the open air, what effect is produced? What is the effect if the bottle is filled with air and placed in an atmosphere of hydrogen? Explain Fig. 70. Mention some of the results obtained by this apparatus.

197. What facts are mentioned to illustrate the action of moistened bladder?

latter escapes into the atmosphere of carbonic acid. If the bladder were perfectly dry, it would not distend in carbonic acid; the endosmose of the carbonic acid is, therefore, owing to its absorption by the water of the moistened bladder, by which it is transmitted to the inner surface of the bladder, and there given up to mingle with the air. A bladder moderately wet, expands more than one that is thoroughly soaked, for the thinner the film of water that absorbs the gas, the sooner will the gas reach the opposite surface. If the bladder containing air be moistened with alcohol (which absorbs carbonic acid more readily than water does), it will expand in an atmosphere of carbonic acid as quickly as if it were moistened with water, but not more so. If, on the other hand, the bladder be rubbed with olive oil, or oil of anise (neither of which absorbs carbonic acid), it will not expand in carbonic acid. In sulphuretted hydrogen a wet bladder containing air will expand more quickly than in carbonic acid, and, after being distended as far as possible in carbonic acid, it will expand still further if placed in an atmosphere of sulphuretted hydrogen.

198. When gases are generated in *earthenware* retorts, or conducted through earthenware tubes, portions of these gases escape through the pores, and are replaced by air entering from without. When these earthen vessels are placed in the fire, nitrogen and carbonic acid enter in place of the gas which escapes. If we heat water, hydrate of lime, or moist clay, in an earthen retort, either to redness, or just above the boiling point of water, very little water is evolved at the end of the retort, the greater part escaping through the pores; but there is obtained a great quantity of atmospheric air, which sometimes amounts to $\frac{9}{10}$ of the weight of the water present, but contains less oxygen and more carbonic acid (derived from the fire), than common air. If the retort is inclosed in a receiver, (Fig 71.) standing over mercury, the neck of the retort passing, air-tight, through an opening in the top, and

Fig. 71.



Why is it necessary that the bladder should be moist? What effect is produced by moistening the bladder with alcohol?—by rubbing it with olive or anise oil? What is the action of a moistened bladder in sulphuretted hydrogen?

198. What effect is produced when gases are generated in earthernware retorts or conducted in earthernware tubes?—when these earthern vessels are placed in the fire?—by heating water, hydrate of lime, or moist clay, in an earthern retort? Explain Fig. 71. Whence is the air that issues from the end

heat is applied by means of a large lens, a considerable quantity of air issues from the open end of the retort, water collects over the mercury in the receiver, and this (the mercury), rises 3½ inches, if the retort is made of compact earthenware, and to a smaller height if it is more porous. The air that issues from the end of the retort, is derived in part from that which penetrates the retort from the receiver by exosmose, while, by endosmose, the watery vapor escapes into the receiver, where it is condensed on the surface of the mercury. If the receiver contains hydrogen, or nitric oxide, these gases, in the same way, issue from the open end of the retort, and the mercury also rises in the receiver. From the same cause, when the vapor of water is passed through the tube of a tobacco-pipe heated to redness, a mixture of gases is obtained, differing little from common air. The same phenomena are exhibited by vessels, or tubes, of chalk, or white marble. The mixing of gases through earthenware retorts, explains the incorrect results which chemists formerly obtained. It was formerly supposed that the vapor of water was converted into nitrogen gas, by being passed through red hot tubes.

METALLIC ELEMENTS.

199. The metals are forty-nine[*] in number. Of these, seven, viz., gold, silver, mercury, copper, iron, tin, and lead, were known to the ancients; the remainder have been discovered within a period comparatively recent, and most of these within the last half century.

200. The properties of metals may be divided into the *general properties*, or those which are common to all metallic

[*] Fifty-one, if niobium and ilmenium be included.

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of the earthern retort derived? Whence is the water that is condensed on the mercury obtained? What effect is produced when hydrogen or nitric oxide surround the retort in the receiver? What is the effect of passing the vapor of water through the tube of a tobacco-pipe heated to redness? Why did chemists formerly suppose that watery vapor was converted into nitrogen in passing through red-hot tubes?

199. What is the number of metals at present known? How many of these were known to the ancients?

bodies, and distinguish them from bodies not metallic, and the *peculiar properties*, or those which belong to and characterize particular classes of metals.

The *general properties* of metals are: (1.) They are all conductors of heat and electricity. (2.) All metals possess a peculiar lustre, so characteristic as to be called the *metallic lustre.* This property is doubtless connected with an extraordinary degree of opacity which the metals present in every instance. The thinnest leaves or plates, the edges of crystaline laminæ, arrest the passage of light in the most complete manner. Even the greenish color of gold leaf, when held up to the light, is probably owing to the passage of light through innumerable holes, produced by beating the leaf to great fineness. The metallic lustre is destroyed by every cause which breaks the continuity of the surface, as when the metals are reduced to powder, or when a rough surface is produced by casting. In the latter case it may sometimes be restored by pressure with a burnisher, as in castings of gold and silver. (3.) All the metals combine with oxygen, and, when thus combined, they generally lose their metallic lustre. (4.) When the compounds of the metals are submitted to the action of galvanism, the metals appear at the *negative pole* of the battery. (5.) All the metals are combustible. Zinc burns with a brilliant flame, when heated to redness in the open air; iron burns splendidly in oxygen gas, and the most refractory metals burn under the flame of the oxy-hydrogen blowpipe.

Among the *peculiar properties* of metals, or those properties which belong not to all, but to certain classes of metals, are: (1.) Malleability, or the property of being extended under the blows of the hammer. (2.) Laminability, or the property of being rolled out into sheets. Tin and platinum are easily rolled out into foil. Silver bars are rolled out into strips, for the manufacture of spoons and coin. Iron and zinc are rolled out into sheets. (3.) Ductility, or the property of being drawn out into wire. Nearly all the malleable metals are also ductile; but this is not always the case. Iron, for example, cannot be beaten out into thin laminæ, but it may be drawn into fine wire. Dr. Wollaston devised a method by which gold wire might be obtained, so

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200. How may the properties of the metals be divided? State the general properties of metals. With what is the peculiar lustre of metals connected? How may this lustre be destroyed? How may it be in some cases restored? What effect has combination with oxygen upon the lustre of metals? What is the action of galvanism upon the compounds of metals? What examples are

fine that its diameter was only $\frac{1}{5,000}$ of an inch, and 550 feet of it weighed only a grain. He obtained a platinum wire so fine, that its diameter did not exceed $\frac{1}{3,000}$ of an inch. (4.) Metals differ very much in their specific gravities. Potassium and sodium are lighter than water, while platinum is nearly 21 times heavier than that fluid.

Table of specific gravities of metals at 60°.

Platinum	20·98.	Bismuth	9·82.	Zinc	6·86 to 7·1.
Gold	19·26.	Copper	8·89.	Manganese	6·85.
Tungsten	17·60.	Cobalt	8·54.	Antimony	6·70.
Mercury	13·57.	Arsenic	5·88.	Titanium	5·30.
Lead	11·35.	Iron	7·79.	Sodium	0·972.
Silver	10·47.	Tin	7·29.	Potassium	0·865.

(5.) Metals differ as much in fusibility as in density.

Class I.—*Metals fusible below a red heat* (1,000°.)

Mercury,	—39°.	Bismuth	497°.
Potassium	136°.	Lead	612°.
Sodium	190°.	Zinc	773°.
Tin	442°.	Antimony, just below redness.	

Class II.—*Metals infusible below a red heat.*

Silver	1873°.	Gold	2016°.
Copper	1996°.	Cast iron	2786°.

Class III.—*Metals difficult of fusion in a wind furnace.*

Cobalt.	Tungsten,	imperfectly melted.
Manganese.	Chromium,	

Class IV.—*Metals infusible in a wind furnace, fusible by the oxy-hydrogen blowpipe.*

Titanium.
Iridium.
Rhodium.
Platinum.

Some metals acquire a pasty or adhesive state, before becoming fluid. This is the case with iron and platinum, and with sodium and potassium. It is this peculiarity which confers the valuable property of *welding*, by which pieces of

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given of the combustion of metals? State the properties which are peculiar to classes of metals. What four metals possess the property of welding? To what is this property owing? Mention some of the volatile metals.

iron and steel are united without solder, and finely divided platinum sponge is converted into a solid and compact bar.

(6.) Volatility is possessed by some of the metals, and perhaps, by all, could temperatures sufficiently elevated be obtained. Mercury boils and distils below a red heat; potassium and sodium, and zinc and cadmium, rise in vapor, when heated to bright redness: mercury, arsenic, and tellurium are volatile.

(7.) The metals differ greatly in their attraction for oxygen. Potassium and sodium are oxidized by mere exposure to the air, and they decompose water at all temperatures when they come in contact with it, taking from the water its oxygen by which they are oxidized. Iron and copper may be exposed in dry air without change, but they are slowly oxidized, by exposure to a moist atmosphere, and combine rapidly with oxygen, when heated to redness in the open air. The affinity of copper for oxygen, is less than that of iron, and that of mercury, is less than that of copper. Pure mercury does not attract oxygen from the air, but its amalgams quickly become oxidized. Gold will bear the most intense heat of a wind furnace without oxidizing.

(8.) Many of the metals have a structure decidedly crystaline. Iron is fibrous; zinc, bismuth, and antimony, are lamellated, or crystalized in thin plates. Gold, silver, and copper, occur naturally in crystals, and other metals crystalize when they are gradually cooled from the melted to the solid state.

201. *Metallic Combinations.* These are of two kinds; those formed by the union of the metals among themselves, and compounds with the non-metallic elements. The former are called alloys, or amalgams, where one of the metals is mercury. The latter are called oxides, chlorides, sulphurets, &c., according as the non-metallic element is oxygen, chlorine, sulphur, &c. When an acid is united to an oxide, the resulting compound is called a salt. These salts and oxides will be conveniently considered under the metals to which they belong.

202. The metals are arranged according to the relations of their oxides to the reagents employed in chemical analysis.*

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* A very interesting series of experiments may be given in illustration of this table; this series may be more or less full according to circumstances. It will be unnecessary at present to commit the table to memory, as questions on the peculiar properties of each group will be given after the metals of that group have been described.

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201. Of what two kinds are metallic combinations? What is meant by the term alloy?—amalgam?—oxide, chloride, sulphuret, &c.?—metallic salt?

FIRST GROUP. THE ALKALIES.

Metals—potassium, sodium, ammonium, lithium.

Oxides—potash, soda, ammonia, lithia;—not precipitable by sulphuretted hydrogen, nor by hydrosulphuret of ammonia, nor by the alkalies, (i. e. by each other.)

The metals of this group are lighter than water. They decompose water at ordinary temperatures, with liberation of hydrogen. Their compounds with chlorine, bromine, iodine, sulphur, and oxygen, are soluble in water, as are also the combinations of their oxides, with most acids.

SECOND GROUP. THE ALKALINE EARTHS.

Metals—barium, strontium, calcium, magnesium.

Oxides—baryta, strontia, lime, magnesia;—not precipitable by sulphuretted hydrogen, nor by hydrosulphuret of ammonia, but *precipitable by alkaline carbonates and phosphates.*

With carbonic and phosphoric acids, the oxides of these metals form compounds that are insoluble in water, in which respect they differ from the oxides of the last group. The metals of this, like those of the last group, decompose water, and their compounds with oxygen and sulphur are soluble in water, though less so than those of the alkaline metals.

THIRD GROUP.

Metals—aluminium, chromium.

Oxides—alumina, chrome;—not precipitable by sulphuretted hydrogen, *precipitable by hydrosulphuret of ammonia.*

The oxides of these metals are insoluble in water, in which they differ from the metallic oxides of the previous groups. These metals also do not decompose water, unless it contains a free acid.

FOURTH GROUP.

Oxides of manganese, iron, zinc, nickel, cobalt;—not precipitable by sulphuretted hydrogen, *in solutions containing a free acid, but precipitable from alkaline solutions.*

These metals, like those of the last group, decompose water in the presence of acids, with evolution of hydrogen. The oxides of this group, with the exception of the oxide of zinc, are insoluble in solutions of potash, in which they differ from the oxides of the preceding group.

FIFTH GROUP.

Oxides of bismuth, copper, lead, mercury, cadmium, silver, palladium, rhodium, osmium;—*precipitable by sulphuretted hydrogen.*

The oxides and sulphurets of these metals possess the properties of their bases, in which they differ from the metals of the next group, whose compounds, with oxygen and sulphur, possess the properties of acids.

SIXTH GROUP.

Tin, antimony, arsenic, gold, platinum;—*not precipitable by sulphuretted hydrogen from alkaline solutions, but precipitable from acid solutions.* (See fourth group.)*

METALS OF THE ALKALIES.

POTASSIUM, 0·865. 39. K.

203. At the head of each of the metals will be placed the name of the metal, its specific gravity, its combining number, and its symbol, in this order. Thus, this metal is potassium, its specific gravity is 0·865, its combining number is 39, and its symbol is K.

The properties of potassium are so remarkable, that it was for sometime doubted whether it could be placed among the metals. One of its most remarkable properties is its lightness, which enables it to float on water. Another of its striking properties is its intense affinity for oxygen.(106) In this respect it probably surpasses all other bodies, and is, therefore, frequently used in decomposing metallic oxides otherwise not easy of reduction. It absorbs oxygen from both water and air, burning when thrown on water, and becoming tarnished when exposed to the air. It is, therefore, kept under naptha, a fluid which contains no oxygen. Its melting point is very low. It becomes soft at 80°, and perfectly fluid at 150°. In color and lustre it resembles

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* At the end of the metals (328.) will be found a complete list of these bodies, with their specific gravities, combining numbers, and symbols.

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203. Write the specific gravity, combining number, and symbol of potassium. What are some of the most striking properties of this metal? Mention some of the other properties of potassium.

mercury. It crystalizes, by sublimation, in cubes, and its cut surface exhibits cubical markings. At 32° it is brittle; at 66·2 it is as soft as wax. It sublimes in green vapors at a temperature below redness. Potassium forms an amalgam with mercury.(107)

204. *Hydrate of potash, caustic potash,* KO, HO. When a solution of carbonate of potash is boiled with quicklime, the lime takes the carbonic acid, and the potash is reduced to its caustic state.

KO, CO_2 = carbonate of potash.
CaO = lime.
Bring down the CO2 to the CaO, and there is produced
KO = CAUSTIC POTASH.
(remains in solution.)
CaO, CO_2 = carbonate of lime, insoluble.
(precipitates from solution.)

The hydrate of potash is also formed when potassium is exposed to moist air, which is rapidly oxidized, and at the same time absorbs moisture.

Pure hydrate of potash, is a white, hard, brittle substance, very deliquescent (108), and soluble in water. Alcohol also dissolves it freely, which is the case with comparatively few of the compounds of potassium. Alcohol may, therefore, be used to purify the solid hydrate of commerce. It melts below redness, and volatilizes at a full red-heat, in white pungent vapors. The solution of this substance possesses in the very highest degree the properties termed alkaline, and, therefore, of all the bases, it possesses the strongest affinity for most of the acids (2nd law of affinity, page 61). It neutralizes completely the most powerful acids, and is most destructive of all the alkalies to organic substances. The alkaline reaction usually predominates in its salts formed with the weaker acids. It is constantly employed by surgeons as a cautery, for which purpose it is moulded into sticks.

In the solid state, and in solution, hydrate of potash rapidly absorbs carbonic acid from the air; hence it must be kept in closely stopped bottles. This solution is employed in analysis, where the quantity of carbonic acid contained

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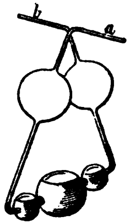
204. Write the symbol of caustic potash. In this symbol what does KO, stand for? Ans.—The oxide of potassium or potash. What does HO stand for? Ans.—Water. How then is the whole symbol to be interpreted? Ans.—The hydrate* of the oxide of potassium, or the hydrate of potash. How is caus-

* From a Greek word meaning water.

in the body under examination is to be determined. The arrangement is represented in Fig 72. The gas from the substance under examination, enters the tube at *a*, and passes through the three lower bulbs, which are about two-thirds filled with solution of caustic potash. This solution absorbs all the carbonic acid from the gas which then passes off through the tube *b*. The bulbs, with the potash solution, are weighed before and after the process, and the increase in weight shows the amount of carbonic acid absorbed.

Fig. 72.



The water of the hydrate of potash cannot be displaced by heat, the whole compound volatilizing at a very high temperature. This is, therefore, called the water of constitution, (see questions p. 98.)

205. *Carbonate of potash*, KO, CO_2+2HO. This substance is the common potash of the shops. It is obtained by the following, or a similar process:

Water is poured upon wood ashes, and the mixture stirred till the potash, (carbonate of potash,) contained in these ashes, is dissolved. The mixture is then allowed to stand, when the greater part of the solid matter settles, and the clear liquor is poured off. This is boiled down until it becomes quite thick, so as hardly to be liquid. It is now allowed to cool, and, when cooled, it becomes a solid mass of carbonate of potash. In this state, it is called *gray salts*. This is dissolved and boiled down a second time, when it forms what is called *white salts*. When pulverized, this constitutes *pearlash*.

Carbonate of potash, though found in the ashes, is not contained in the wood of plants. In all land plants, potash exists in combination with a vegetable acid. This acid is converted by burning the plants into carbonic acid, and the potash thus left in the state of a carbonate. Potash is contained very unequally in plants. Shrubs contain three times, and herbs five times as much saline matters as trees, and in the latter, the branches are more productive than the trunks.

Carbonate of potash is extremely deliquescent, and soluble in less than its own weight of water at 60°. Its solution

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tic potash prepared? Explain Fig. 72. What is said of the water of the hydrate of potash? Write the symbol of carbonate of potash. How is this symbol to be interpreted? Ans.—The carbonate of the oxide of potassium +2 eq. of water, or the carbonate of potash +2 eq. of water. How is carbonate of potis highly alkaline to test-paper. It is insoluble in alcohol. By heat, the water of crystalization is driven off, and, by a temperature of full ignition, the salt is fused, but the carbonic acid is not expelled, as it is from most of its combinations by heat. The vapor of water passed over it at a red-heat, decomposes it, forming hydrate of potash, and setting free the carbonic acid. When heated to whiteness with charcoal, it is also decomposed, and the metal potassium is reduced with the evolution of carbonic oxide gas.

206. *Bicarbonate of potash*, $KO, CO_2, + HO, CO_2$. This salt is formed by passing a stream of carbonic acid through a cold solution of carbonate of potash. The gas is rapidly absorbed, and a white, crystaline, less soluble substance, separates, which is the new compound. This is collected, pressed, redissolved in warm water, and the solution left to crystalize.

Bicarbonate of potash requires for its solution 4 parts of cold water, at 60°, and less water at 212°. The solution is nearly neutral to test-paper, and has a much milder taste than the carbonate of potash, for which reason it is more often used in medicine. It forms large, beautiful crystals. These are very easily decomposed; for when they are heated they evolve water and a portion of their carbonic acid, and are thus converted from the bicarbonate to the carbonate of potash. The solutions of this salt decompose by evaporation at all temperatures, losing carbonic acid, and being converted into a neutral carbonate of potash.

207. *Sulphate of potash*, KO, SO_3, may be prepared by adding carbonate of potash to sulphuric acid, until the solution becomes neutral. This solution, when concentrated, affords hard transparent crystals, which are redissolved in boiling water, and recrystalized. They resemble crystals of quartz (166.) in figure and appearance, are anhydrous, unalterable in air, and decrepitate strongly when heated. They dissolve in about 10 parts of cold, and in a much smaller quantity of boiling water. Sulphate of potash has a bitter taste, and is neutral to test-paper.

208. *Nitrate of potash, nitre, saltpetre*, KO, NO_5. This

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ash obtained? Is this salt contained in the wood of plants? Why is it found in the ashes? State some of the properties of carbonate of potash.

206. Write the symbol of bicarbonate of potash. How is this symbol to be interpreted? Ans.—Carbonate of potash with an eq. of carbonated water. How is bicarbonate of potash formed? State some of its properties.

207. Write the symbol of sulphate of potash. How is this symbol to be interpreted? State the process for preparing sulphate of potash. Mention some of its properties.

important compound is a natural product, being disengaged by a kind of efflorescence from the surface of the soil in certain dry and hot countries. Nearly all the nitre of commerce comes from India, where it is a natural product. In France, large quantities of artificial nitre are prepared, by mixing masses of putrid animal matter with lime. The nitrogen of the decaying animal matter unites with the lime to form nitrate of lime; this is afterwards mixed with carbonate of potash, when a double exchange takes place:

KO, CO_2 =carbonate of potash.
CaO, NO_5=nitrate of lime.

By double exchange

KO, NO_5 =NITRATE OF POTASH, soluble salt.
(dissolved out from the insoluble carbonate of lime.)

CaO, CO_2=carbonate of lime, insoluble salt.
(remains after the nitre is dissolved out.)

The symbol for nitre, KO, NO_5, shows a very large amount of oxygen. To this fact, and to the feeble affinity by which the oxygen is held, it is owing that this salt has great power in promoting combustion. A weak solution, poured over cloth or paper, will cause them when dry to burn rapidly on applying a lighted coal. For the same reason, nitre is employed in the manufacture of gunpowder. The following table shows the composition of three different kinds of powder:

	Nitre.	*Sulphur.*	*Charcoal.*
Common powder,	75	12½	12½.
Shooting powder,	78	10	12.
Blasting powder,	65	20	15.

When gunpowder is fired, the oxygen of the nitre is transferred to the carbon, forming carbonic oxide, the sulphur forms with the potassium sulphuret of potassium, and the nitrogen is set free. The large volume of gas from the nitrogen and the carbonic oxide, is still further expanded by the very high temperature, and produces the powerful explosive effects of gunpowder. The gas evolved, when

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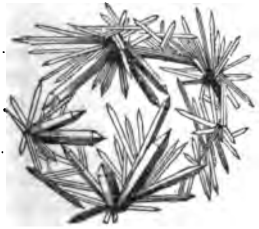
208. Write the symbol of nitrate of potash. Explain this symbol. What is the chief source of this salt ? How is saltpetre manufactured in France ? Explain the diagram. How much oxygen does the symbol of nitre show that it possesses ? Ans.—Six equivalents. To what is the great power which this salt possesses in supporting combustion owing ? When gunpowder is fired, what gases are formed ? What solid substance is formed ? Ans.—Sulphuret of potassium, a salt of dark gray color, which, blackened with carbon, is the residue left by the explosion of gunpowder. How much does the gas evolved in the explosion of gunpowder exceed in bulk the powder ? Upon

measured cold, is about 300 times the gunpowder in volume, but, from its high temperature, it is probable that it expands at least 1000 times. Its instantaneous combustion, and, consequently, its explosive energy, depends upon its *granulation*, for when powder is not granulated, or when the granulation is destroyed, the gunpowder burns rapidly, but without explosion. By granulation the flame is able to penetrate the whole mass more rapidly, and to produce an explosion nearly instantaneous. Still, the discharge of gunpowder occupies a perceptible interval of time, as may be shown by burning a line of powder in connection with a parallel line of some fulminating powder, as fulminating mercury, of equal length. The line of common powder will occupy a perceptible interval in its discharge, while that of fulminating powder will appear to flash instantaneously. Mining and blasting powder is frequently mixed with a considerable quantity of sawdust, the object of which is to prolong the discharge, and thus to render the powder more effectual. Fulminating powders are found not to be adapted for fire-arms, for their explosion is so nearly instantaneous, that the effect which they produce is almost wholly local, bursting the musket without projecting the ball. *A sustained effort* is found necessary to the best effect, both in fire-arms and in blasting rocks.

In nearly all fire-works, nitre is employed to supply oxygen for the ready combustion of the various materials.(109) Nitre is also largely used in freezing mixtures to generate cold.(110) Its crystaline form is very beautiful (Fig. 73.) It is crystalized by cooling a hot saturated solution in a bottle, or on a slip of glass. The crystals are anhydrous, but they often hold a portion of liquid, mechanically lodged within the substance of the crystals. As this is particularly the case with large crystals, it is sometimes necessary to agitate the solution while crystalizing, to obtain small crystals. Crystals of a large size crack with the warmth of the

Fig 73.



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what does the instantaneous explosion of powder depend? How does granulation produce this effect? Is the discharge of gunpowder absolutely instantaneous? How may this be shown? Why are not fulminating powders suitable for fire arms? For what purpose is nitre employed in fire-works? What does Fig. 73 represent? What are some of the properties of crystalized nitre?

hand. Their taste is sharp, bitter, and cooling. They are fusible into a limpid liquid, by a heat under redness. Their solution has considerable antiseptic properties, and is therefore sometimes employed in preserving meats, especially beef, to which it communicates a red color and considerable firmness.

209. *Chlorate of potash*, KO, ClO_5. Oxygen is the chief constituent of this salt, and is held by a very weak affinity. To this fact are to be ascribed its peculiar and striking properties. On the application of heat it is decomposed, affording pure oxygen. With certain bodies it unites to form explosive compounds, some of them of the most terrible kind. With other combinations it explodes by friction, and is, therefore, now a large article of commerce, being employed with phosphorus in the manufacture of matches. When in powder it detonates with a blow. It forms, also, compounds that take fire with acids. The *percussion powder* is a mixture of chlorate of potash with sulphur, or other combustibles.

Chlorate of potash is soluble in about 20 parts of cold and 2 of boiling water. Its crystals have a pearly lustre, and are flat, tabular, and anhydrous. Their taste is cooling, and slightly bitter, resembling the taste of nitre. From the great amount of oxygen which it contains, chlorate of potash imparts a bright scarlet color to the venous blood, and is used in medicine as a remedy for certain fevers.

210. *Iodide of potassium*, KI. When iodine is added to a strong solution of caustic potash, free from carbonate, it is dissolved in large quantity. The solution thus formed consists of two salts,—iodide of potassium, and iodate of potash. When sufficient iodine has been dissolved to color the solution permanently, this is evaporated to dryness, and cautiously heated red hot. By this means the iodate of potash is entirely converted into the iodide of potassium. The mass is then dissolved in water, and, after filtration, made to crystalize. Its crystals are cubes, which are often milk-white and opaque. They are anhydrous, and fuse readily when heated. They are very soluble in water, but not deliquescent in a moderately dry atmosphere. They are solu-

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209. Write the symbol of chlorate of potash. Explain this symbol (chlorate of the oxide of potassium, or potash.) How much oxygen does the symbol of chlorate of potash show that it possesses? To what are the peculiar properties of this salt to be ascribed? Mention some of these properties.

210. What is the symbol of iodide of potassium? How is this salt prepared? State some of its properties.

ble also in alcohol. Solution of iodide of potassium, like those of all the iodides (in water), dissolves a large quantity of free iodine, forming a deep-brown liquid.

211. The salts of potash are more or less soluble in water, and are distinguished by a white, crystaline precipitate, formed with tartaric acid. The precipitate is not usually formed until sometime after the tartaric acid is added, and this effect is greatly promoted by agitation. The most important of the *liquid* tests for potash, is that with the chloride of platinum, which throws down, in a concentrated solution, a yellow crystaline precipitate. The solution in this case should not be alkaline, but rendered neutral, or acid, by the addition of hydrochloric acid. Ammonia produces a similar precipitate, but the compounds of ammonia are easily distinguished from those of potash. The former, when heated, especially with quicklime, lose their ammonia, which is known by its smell, and its reaction with hydrochloric acid (p. 137), while potash remains *fixed*. The delicacy of the tests with chloride of platinum and tartaric acid, is increased by the addition of alcohol. Salts of potash also give a characteristic purple tint to the outer blowpipe flame.

The salts of potash add greatly to the fertility of the soil, and are particularly adapted for those plants in the ashes of which, when burnt, these salts are found most abundantly, as for grape-vines, potatoes, turnips, &c. In the siliceous plants these salts, or those of soda, are essential to render soluble the silica which these plants contain. They also combine with and render soluble the vegetable matter of the soil, so as to bring this into a state in which it may be readily conveyed into the roots. They promote certain changes in plants, to be described hereafter, which are essential to the production of the living vegetable, and their presence in the soil enables it to obtain a supply of nitrogen from the atmosphere, and to bring this nitrogen, in the form of nitric acid, to the roots of plants. Finally, as most plants contain potash and soda, the presence of the salts of these alkalies in the soil is essential to their growth.

SODIUM, 0·972 23 Na.*

212. Sodium is a silver-white metal, with a high lustre. It greatly resembles potassium in every respect. It is soft

* Latin, *natron*, soda.

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211. What are some of the tests for the salts of potash? What is said of the use of these salts in agriculture?

at common temperatures; melts at 194°, and oxidizes very rapidly in the air. Like potassium, it floats on water, but does not decompose the water with as great energy as that substance. On cold water it floats about without burning; but on hot water it takes fire, burning with its characteristic yellow flame, and giving rise to a solution of soda. It crystalizes in cubes. At 40° below zero it is rather hard; at 32° it is ductile; at 122° semi-fluid; and at 194° perfectly fluid. It is an excellent conductor of heat and electricity. Potassium does not unite with mercury, but sodium and mercury unite even with explosion.(111)

213. *Hydrate of soda, caustic soda,* NaO, HO. The process by which caustic soda is obtained, is precisely similar to that for caustic potash (204.) Carbonate of soda is boiled with quicklime; the lime takes the carbonic acid, and the soda is reduced to the caustic state:

NaO, CO_2=carbonate of soda.
CaO =lime.
Bring down the CO2 to the CaO, and there is produced
NaO =CAUSTIC SODA.
(remains in solution.)
CaO, CO_2=carbonate of lime, insoluble salt.
(precipitated from solution.)

The solid hydrate of soda is a white, fusible substance, very similar in its properties to hydrate of potash. It is deliquescent, but dries up again after a time, in consequence of the absorption of carbonic acid. The solution is highly alkaline, and a powerful solvent for animal matter.

214. *Sulphate of soda, Glauber's salts,* $NaO, SO_3 + 10\,HO$. Sulphate of soda is the substance left in the retorts, used for the manufacture of hydrochloric acid, or any process where sulphuric acid is added to common salt, (p. 102.) Its crystalization is exceedingly beautiful, resembling that of nitre, (Fig. 73.) The crystals contain 10 eq. of water, and are efflorescent, and undergo watery fusion when heated. They are soluble in twice their weight of cold water, and rapidly increase in solubility, as the temperature of the liquid rises to 91·5°, when a maximum is reached. At this temperature, 100 parts of water dissolve 322 parts of the

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212. Write the specific gravity, combining number, and symbol of sodium. Mention some of the properties of this metal.

213. Write the symbol of caustic soda. Explain this symbol. State the process for preparing soda. Explain the diagram. What are some of the properties of hydrate of soda?

214. Write the symbol for sulphate of soda. Explain this symbol. How is

salt. Heated beyond this point, the solubility diminishes, and a portion of the sulphate is deposited. A warm, saturated solution, evaporated at a high temperature, deposits opaque, prismatic crystals, which are anhydrous.

This salt is purgative, and is therefore sometimes used in medicine, although, on account of its very nauseous and bitter taste, it is almost superseded by sulphate of magnesia. It is also called Glauber's salts, from the physician who discovered it. It is found in many mineral waters.

215. *Carbonate of soda*, $NaO, CO_2 + 10 HO$. The crystalized carbonate of soda, contains the same large proportion of water ($10 HO$), as the crystalized sulphate. This is the common soda of the shops. It was formerly obtained from the ashes of sea-weed. The barilla, a coarse kind of carbonate of soda, sometimes employed in soap making, is made from several varieties of sea-weed, that grow on the coast of Spain. It is usually manufactured from common salt. The salt is first converted into the sulphate, by the addition of sulphuric acid. The hydrochloric acid driven off in this process, is saved by being passed through water. The sulphate of soda thus made, is reduced to powder, and mixed with an equal weight of chalk, or limestone, (carbonate of lime,) and half as much coal, both ground and crushed. This mixture is heated to fusion in a furnace, with constant stirring. When the decomposition is judged complete, the melted matter is raked from the furnace into an iron trough, where it is allowed to cool. When cold, it is broken up into little pieces, and lixiviated with cold, or tepid water. The sulphuric acid of the sulphate of soda, is transferred by double decomposition to the lime, forming sulphate of lime, an insoluble salt; the carbonic acid of the carbonate of lime uniting with the soda, forms carbonate of soda, which being soluble, is dissolved out by lixivation from the insoluble sulphate of lime:

NaO, SO_3=sulphate of soda.
CaO, CO_2=carbonate of lime.

By double exchange

NaO, CO_2=CARBONATE OF SODA.
[dissolved out by lixiviation.]
CaO, SO_3=sulphate of lime, insoluble salt.

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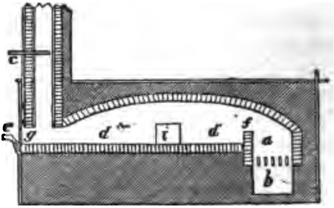
this salt obtained? What is said of its crystalization, and other properties? What is said of its use in medicine?

215. Write and explain the symbol of carbonate of soda. How was this salt

The solution of carbonate of soda thus formed, is evaporated to dryness, and the salt calcined with a little sawdust in a suitable furnace. The product is the soda-ash of commerce. About 50 per cent. of this is pure carbonate of soda. By dissolving soda-ash in hot water, filtering the solution, and then allowing it to cool slowly, the carbonate is deposited in large transparent crystals.

The roasting of the sulphate of soda with lime, is performed in a furnace of peculiar construction, which is often used for similar processes in the arts. In Fig 74, *a* is the grate, *b* the ash pit, *c* the chimney, *d d* the hearth for receiving the mixture, *i* the aperture for throwing in the mixture, and *g* an opening for stirring it, and scooping it out. These are called *flame furnaces*, or *reverbatory furnaces*, because the heating is not effected by the ignited coal of the fuel, but by the flame passing over the bridge *f*. By this arrangement the substance heated, or *roasted*, is kept free from the ashes of the fuel.

Fig. 74.



216. In the *manufacture of glass*, potash or soda forms the basis. Glass is a silicate of potash or soda, or a compound of silicic acid and potash, or soda. To the silica and soda, or potash, a variety of substances are added, to make the glass more colorless, dense, and transparent. Lead promotes fusibility, confers density and lustre, and gives tenacity to the glass while red hot. It enables the glass to bear sudden changes of heat and cold, and improves its refractive power, by which it is rendered more valuable in the manufacture of optical instruments, as the microscope, telescope, &c. Black oxide of manganese is used to destroy the slight green color given by impure potash or soda. Unless used in very minute quantity, it imparts a purple tint to the glass. Arsenic is also sometimes employed. The ingredients are first roasted to a red heat, to expel moisture and carbonic acid (from carbonate of soda, which is thus reduced to caustic soda—the alkalies can only be used in their caustic state in the manufacture of glass and soap.) After being roasted, the materials are ground up

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formerly obtained? From what is it now manufactured? State this process, and explain the diagram. Explain Fig. 74. What are these furnaces called?

216. What is the composition of glass? Why is lead added to glass?—manganese? What other substance is sometimes employed? Explain the process

together. The glass pots, or retorts, are then put into a furnace, (Fig. 75.) which has as many doors, *d*, as the number of retorts, *r*, it is capable of heating. In Fig. 76, the retorts are seen in their position, on a platform around a central grate, through which the heat and flame from the furnace enter. When melted, the glass is taken out on hollow iron rods, to which it readily adheres, and it is then blown by the workman into decanters, bottles, and other articles, or is poured on a table to form sheet or plate glass. When cold enough to handle, the glass is carried to an oven, where it is again heated. It is then taken to the annealing oven, (Fig. 77.) One end of this oven (the most distant in this figure), is kept at a high heat, and the glass vessels are placed on sliding pans, which are covered with sand. These pans are drawn along from time to time by simple machinery, consisting chiefly of a crank, rollers, and an endless chain. When the glass vessels reach the cool end of the oven, which generally takes place in from one to two days, or even longer, they are annealed, and by this process rendered much less brittle, and less liable to crack by sudden changes of temperature. When the annealing oven is full, as fast as one pan is removed at the cool end of the oven, another is introduced at the same time at the end which is kept at a high heat. In making the large circular *tables* of crown glass, a globular flask of great size is first produced, and to this a rapid rotary motion is given, until, by centrifugal force, the whole is suddenly made to assume the form of a disc. *Tubes* are made by drawing out a hollow cylinder of partially melted glass.

Fig. 75.

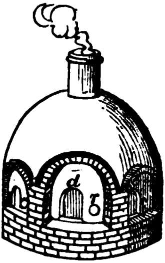


Fig. 76.

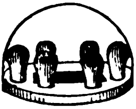
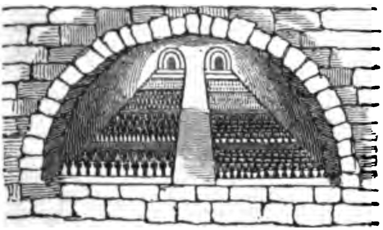


Fig. 77.



Different colors are communicated to glass by metallic ox-

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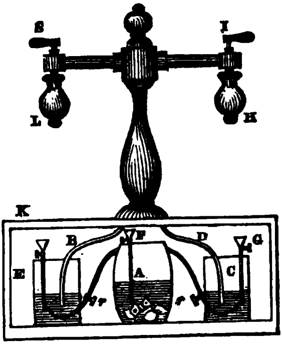
of making glass. How are different colors communicated to glass? What gives a blue color to glass?—green?—violet or amethyst?—red?—ruby-red?—dull green or brown?—purple?—white?—yellow?

ides. Blue glass, is formed by means of an oxide of cobalt; green, by the black oxide of copper; violet, or amethyst, by the oxide of manganese; red, by the mixture of the oxides of iron and of copper; ruby-red, by the sub-oxide of copper; dull green, or brown, by the oxide of iron; purple, by the oxide of gold; white, by the oxides of arsenic and zinc; and yellow, by the oxide of silver.(112)

217. When carbonate of soda is mixed with an acid, the carbonic acid is driven off with effervescence. Hence this salt is used in the manufacture of *soda-water.* Common bottled soda, is made by dropping into a bottle, about two-thirds full of water, a crystal of carbonate of soda, and another of tartaric acid. The bottle is then tightly corked, and the cork tied down. The crystals will gradually dissolve and decompose each other. Carbonic acid rises, and is absorbed by the water, and, when the bottle is afterwards uncorked, the carbonated water flows out with effervescence.

Fig. 78, represents the method of making soda-water in the large way. A is a small strong cask, with a funnel at the top, and two pipes at the sides, all fitting air-tight, and furnished with stop-cocks, F, *r*, *r*. The pipes enter the vessels E and C on each side of A, and extend nearly to the bottom of those vessels. E and C are also furnished with funnels, extended beneath the liquid which they contain. The pipes, B, D proceed upwards to the jets, H and L. The two sides of the apparatus are similar, and may be employed for fountains of two different liquids. If soda-water alone is desired, the apparatus on one side is all that is necessary, but in connection with this, a fountain of ginger-beer, or some other drinks may be employed.

Fig. 78.



The action is as follows. Two or three pounds of chalk, (carbonate of lime,) are put into A, and a gallon of water added. C and E are also half filled with water, either pure or flavored with sugar, ginger, lemons, &c. The cocks, *r*, *r*,

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217. How is common bottled soda-water made? Explain Fig. 78. How is

are now opened, the others being closed. Sulphuric acid is added through the funnel F:

CaO, CO_2 = carbonate of lime.
SO_3 = sulphuric acid.
Bring down CaO, and there is produced
CO_2 = CARBONIC ACID.
(escapes in gas.)
CaO, SO_3 = sulphate of lime, insoluble salt.
(precipitates in the cask A.)

The carbonic acid, being expelled from the chalk in A, passes into the water of C and E, where it is absorbed, and, after the absorption has taken place, accumulates in the upper part of C and E; here it exerts a pressure, which, when the valves I and S are opened, drives the water up the tubes B and D, and out at the jets L and H.

The gas generator, A, is often fixed upon an axis by which it may be made to revolve, and thus the action of the acid on the chalk is promoted. The containing vessels are generally made of wood or earthern ware, as sulphuric acid dissolves iron and zinc rapidly, and carbonic acid acts readily upon copper. The tubes are apt to break at the joints; to remedy this, they should be made of pewter or tin; lead also is sometimes used, but water standing in contact with lead, frequently acquires poisonous properties, by a slight corrosion of the lead.

When the apparatus is fully charged with carbonic acid, *no more will be formed in* A. Thus, there is no waste of materials employed in generating the gas. The pressure of the gas, however, is frequently so great as to burst the apparatus, and fatal accidents have occurred in this way.

218. *Bicarbonate of soda*, $NaO, CO_2 + HO, CO_2$. From this symbol it appears, that the bicarbonate of soda consists of the carbonate of soda, (NaO, CO_2), and carbonated water (HO, CO_2). It is prepared by passing carbonic acid gas into a cold solution of the neutral carbonate of soda, or by placing the crystals in an atmosphere of carbonic acid, which they rapidly absorb. The ten equivalents of water of crystalization ($10\,HO$), which the crystals of carbonate of soda contain, they, to a great extent, lose in being converted into the bicarbonate.

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soda water prepared by this arrangement? Explain the diagram? Is the water which is drawn from H and L soda, or merely carbonated water?

218. Write and explain the symbol for bicarbonate of soda. How is this salt prepared? State some of its properties.

Bicarbonate of soda is a white, crystaline powder, which, in solution, loses carbonic acid slowly at the temperature of the air, and rapidly above 160° (206.) By this decomposition, it passes first into a sesquicarbonate, and finally into a neutral carbonate. At 60° it requires 10 parts of water for its solution, which is feebly alkaline to test paper, and has a milder taste than that of the simple carbonate; it is, therefore, more frequently employed in medicine (206.)

219. *Chloride of sodium, common salt*, $NaCl$. The earth and sea abound in common salt. In many places it is found in solid beds, or irregular strata, of immense thickness. The salt of these beds resembles transparent stone, and is therefore called *rock-salt*. It is almost always too impure for use; hence, if no natural brine-spring exists in these beds, an artificial one is formed by sinking a shaft into the rock-salt, and, if necessary, introducing water. This, when saturated, is pumped up and evaporated, more or less rapidly, in large iron pans. As the salt separates, it is removed from the bottom by means of a scoop, pressed, while still moist, into moulds, and then transferred to the drying stove. When large crystals are required, as for coarse *bay salt*, used in curing provisions, the evaporation is slowly conducted. This kind of salt is usually obtained from sea-water; a pound of sea-water contains from one-half to five-eighths of an ounce of common salt. This salt has a slightly bitter taste, owing to the presence of salts of magnesia.

As the natural salt-springs contain much more water than is necessary for the solution of the salt, a cheaper method of evaporation than that by fire is sometimes employed. The salt water is pumped up to the top of a lofty scaffolding, filled up with fagots, and from this height is made to fall by drops through the fagots. It diffuses itself over the branches, and thus presents a very large surface to the air passing through them. A rapid evaporation is in this way obtained. Upon the branches gypsum is first deposited, for this is contained in all natural waters, and, being soluble only in a very large quantity of water, it is deposited when the water is considerably diminished by evaporation. It forms a hard crust upon the branches. When the greater portion of the water is evaporated, the concentrated brine is boiled down in large pans, with constant stirring, and the granular salt which separates is raked out and dried.

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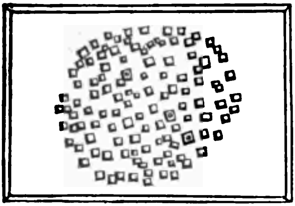
219. Write and explain the symbol of the chloride of sodium. What are some of the more abundant sources of common salt? By what processes is

When pure, chloride of sodium is not deliquescent in moderately dry air. It crystalizes in anhydrous cubes, (Fig. 79.) which are often grouped together in pyramids or steps. It requires about 2½ parts of water, at 60°, for solution, and its solubility is not sensibly increased by heat. In alcohol it is insoluble. By this property, therefore, it may be separated from carbonate of soda. At a bright red heat it fuses, and is volatile at a still higher temperature.

Fig. 79.



We find common salt every where in nature, *because* it is indispensable to the life of animals and plants. Without salt, no complete digestion of food could take place, and it is, therefore, justly regarded as a universal condiment. Animals find it in the meat and plants by which they are nourished; plants receive it from the soil and rain, and the fertility of land is often increased by the application of salt. Wood for the purpose of building, is rendered more durable, by being impregnated with salt.

220. *Nitrate of soda.* NaO, NO_5, occurs native, and in enormous quantity, at Atacama, in Peru, where it forms a regular bed of great extent, covered with clay and alluvial matter. Its crystals are deliquescent, and very soluble in water. It is employed in making nitric acid. It has been substituted for nitrate of potash, (saltpetre,) in the manufacture of gunpowder, but the powder thus made burns too slowly, and becomes damp in the air. It has been used to a considerable extent in agriculture, as a manure. Both this substance, and the nitrate of potash, impart a dark green color to the leaves and stems of plants, hasten, increase, and often prolong their growth. They *generally* cause an increase, both in the weight of hay or straw, and of corn, though the color and growth are occasionally affected without any sensible increase of the crop. The hay and grass produced on meadows when enriched by these nitrates, is always more greedily eaten by the cattle than when these lands are not so enriched; the grain, however, is usually of

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the salt prepared? Explain Fig. 79. Why is common salt so universally diffused in nature?

220. Write and explain the symbol of nitrate of soda. Whence is this salt obtained? What are some of its properties? Why can it not be substituted for saltpetre in the manufacture of gun-powder? What effect do the nitrates of soda and potash produce when applied to the soil?

an inferior quality, yielding a smaller produce of flour, and bringing a somewhat less price in the market.

AMMONIUM, com. num. 18. symbol NH_4.

221. All attempts to isolate this substance have failed, apparently from its tendency to separate into ammonia and hydrogen gas. Thus, when ammoniacal amalgam is made by the action of the galvanic current, it soon decomposes into fluid mercury, ammonia, and hydrogen. The formation of this amalgam from the salts of ammonia, seems to prove that they have a metallic base, although the exact nature of that base is as yet undetermined. The best evidence we have of the existence of the metal ammonium, is the perfect comparison which its salts bear with those of the alkaline metals. The symbol of ammonium is supposed to be NH_4, because ammoniacal amalgam is decomposed into ammonia (NH_3), hydrogen (H), and metallic mercury.

222. *Carbonate of ammonia*, $NH_3\ CO_2$. The carbonate of ammonia has many of the properties of its base. Although chemically combined with carbonic acid, it still emits a pungent odor, and affords an alkaline or basic reaction. Exposed to the air, at common temperatures, it disengages ammonia, loses its pungency, and crumbles down to a soft white powder, which is a bicarbonate of ammonia. The properties of this bicarbonate and those of potash, (206.) and soda (218.), are much milder than those of the carbonates of these bases. When thrown on a hot iron, carbonate of ammonia evaporates without melting.

Carbonate of ammonia is used in medicine as a stimulant, and is frequently employed, under the name of "smelling salts," as a restorative from faintness. It is the chief fertilizing substance produced by the decay of animal and vegetable substances, which contain nitrogen. The odor of stables and manure heaps is owing to the production of carbonate of ammonia. This may be removed by a bowl of sulphuric or muriatic acid, which unites with the ammonia, forming sulphate or muriate of ammonia.

223. *Chloride of ammonium, sal ammoniac*, $NH_4\ Cl$. Sal

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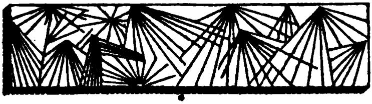
221. Write the combining number and symbol of ammonium. Why have all attempts to isolate the metal ammonium failed? What is the best evidence of the existence of this metal?

222. Write and explain the symbol of carbonate of ammonia. State some of its properties. What is said of the properties of the bicarbonate of ammonia? Mention some of the uses of carbonate of ammonia. How may the odor of stables be removed?

ammoniac is largely manufactured from the ammoniacal liquid of gas works, and from the distillation of bones, and other animal refuse, in the preparation of animal charcoal. The impure and highly offensive solutions thus obtained, are treated with a slight excess of hydrochloric acid, by which the free alkali is neutralized, and the carbonate and sulphate of ammonia decomposed with the evolution of carbonic acid and sulphuretted hydrogen. The free ammonia of these solutions, and that contained in the decomposed carbonate and sulphuret, form chloride of ammonium in the solution. This liquid is evaporated to dryness, and the salt carefully heated to expel and decompose the tarry matter; it is then purified by sublimation in large iron vessels lined with clay and surmounted with domes of lead.

Chloride of ammonium is found native in Italy, and in several other places. When sublimed it has a fibrous texture. It is tough and difficult to powder. When crystalized from water it separates, under favorable circumstances, in distinct cubes, or octahedrons, but the crystals are usually small and aggregated together. If a slip of glass (Fig. 80.) is washed over with a hot saturated solution of sal ammoniac, the moisture will almost immediately be evaporated, and the salt will be deposited in an aggregation of crystals. The same method may often be employed with advantage in crystalizing other substances. If a glass window is painted with a hot saturated solution of sal ammoniac, the salt will be deposited in a very beautiful radiated form, and will admit the light without being transparent. For rendering windows semi-opaque, this method is much preferable to the common way of using paint, paste, and similar materials.

Fig. 80.*



Sal ammoniac is used in tinning iron and copper. These metals are rubbed over with the solution, or dipped into it to prevent the oxidation of their surfaces. In soldering metals it answers a similar purpose. In dyeing it is used to fix, brighten, and modify the colors. It is largely employed in medicine, and is used both internally and externally.

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* These *radii* generally appear of a beautiful aborescent form.

228. Write and explain the symbol of chloride of ammonia. How is sal ammoniac manufactured? Where is this salt found native? What are some of its properties? Explain Fig. 80. For what purposes is sal ammoniac used?

It is employed to form pure and carbonated ammonia, to produce cold, and to excite galvanism. It is also a very valuable reagent in the laboratory.

224. *Hydrosulphuret of ammonia, sulphide of ammonium,* NH_4S+HS, is formed by passing sulphuretted hydrogen through liquor of ammonia to complete saturation. When saturated, it will no longer cause a precipitate in a solution of sulphate of magnesia. The hydrosulphuret of ammonia thus obtained must be kept in well closed bottles, since it is decomposed by contact with the atmosphere. A yellow sulphuret of ammonium is in this case formed. It is invaluable as a reagent in the laboratory (202.), and is also used in medicine.

225. *Nitrate of ammonia,* NH_4O, NO_5, is easily prepared by adding carbonate of ammonia to slightly diluted nitric acid, until neutralization has been reached. The carbonic acid of the carbonate of ammonia is expelled, and nitrate of ammonia formed by the union of the nitric acid with the ammonia. By slow evaporation, at moderate temperatures, it crystalizes in six-sided prisms, like those of nitrate of potash (Fig. 73.) It dissolves in two parts of water, and is feebly deliquescent. Like the other nitrates, it deflagrates on contact with heated combustible matter. Its chief use in the laboratory is in making nitrous oxide gas (174.)

226. The ammoniacal salts are easily known. They are all decomposed or volatilized at a high temperature, and, when heated with hydrate of lime, or solutions of caustic alkalies, they evolve ammonia, which may be known by its odor and its alkaline reaction. The salts of ammonia are more or less soluble. Tartaric acid and chloride of platinum, give the same reaction in ammoniacal solutions as in those of potash, but the former are easily distinguished from the latter, as they volatilize (not only the *ammonia,* but the whole salt) on the application of heat.

LITHIUM, com. num. 6. symbol L.

227. A very rare base, lithia, or oxide of lithium, occurs in several minerals and mineral waters. It possesses properties analogous to those of potassa. Lithium is obtained by electrolyzing the hydrate of lithia in contact with mer-

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224. Write the symbol of hydrosulphuret of ammonia. State the process by which it is prepared. How is it preserved? Mention some of its uses.

225. Write and explain the symbol of nitrate of ammonia. How is this salt prepared? State some of its properties.

226. How are the ammoniacal salts detected?

cury, and then decomposing the amalgam by distillation. It is a white metal, like sodium, and very oxidable. The oxide (LO), is an alkali, but much less soluble than potash or soda. The sulphate of lithia is a very beautiful salt. It crystalizes in lengthened prisms containing one equivalent of water. All the salts of lithia impart a beautiful crimson color to the outer flame of the blowpipe, and to burning alcohol.

METALS OF THE ALKALINE EARTHS.

Barium, 2+. 69. Ba.

228. Barium is procured by heating baryta in an iron tube, through which the vapor of potassium is conveyed. The vapor of potassium takes the oxygen from the baryta, and the metal barium is reduced. The reduced metal is extracted by quicksilver. Barium has the color and lustre of silver. It is ductile, and may be beaten flat, though with difficulty. It fuses below redness, and does not volatilize at a red heat. When exposed to the air, at ordinary temperatures, it becomes covered with a white crust of oxide, and crumbles to a white powder. This oxidation is almost instantaneous, so that, to catch the real color of the metal, the eye must follow the stroke of the file or burnisher. When heated gently, it burns in the air with a dark-red light. In the flame of the oxy-hydrogen blowpipe it burns with a chrysolite-green light. It decomposes water with great energy.

229. *Protoxide of barium, baryta*, BaO. This oxide has an exceedingly strong affinity for water, and, when mixed with it, slakes like lime, though with a more intense heat; this is so great as sometimes to cause the baryta to appear ignited. *The hydrate* is a white, soft powder, having a great attraction for carbonic acid, and soluble in 20 parts of cold and 3 of boiling water. A hot saturated solution de-

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227. Write the combining number and symbol of lithium. Where is lithia found? What is said of its properties? How is the metal lithium obtained? What are its properties? What is said of the sulphate of lithia? How do the alkaline metals differ from those of the alkaline earths? What are the peculiar properties of the alkaline metals as given in art. 202?

228. Write the specific gravity, combining number, and symbol of barium. How is this metal procured? State some of its properties.

posits crystals on cooling. The formula for these is $BaO, HO+9HO$, (1 equivalent of the water of composition and 9 of the water of crystalization.) Solution of hydrate of baryta is a valuable reagent. It is highly alkaline to test-paper, and is instantly rendered turbid by the smallest trace of carbonic acid.

230. *Chloride of barium,* $BaCl+2HO$. The crystals of chloride of barium are flat, four-sided tables, colorless and transparent. They contain 2 eq. of water, which they lose below 212°. At 60° one hundred parts of water dissolve 43·5 of chloride of barium, and 78 parts at 222°, which is the boiling point of the saturated solution. Their taste is sharp and bitter, exciting nauseau. They act on the system as a powerful poison.

Chloride of barium detonates powerfully with combustible bodies. It gives a green light when heated with sulphur, and, when mixed with sulphuric acid, it produces a sudden and vivid flash. It is largely employed in the manufacture of fire-works.

231. *Sulphate of baryta, heavy spar,* BaO, SO_3, is found native in beautiful crystals, sometimes tabular, and sometimes prismatic. It occurs in considerable quantity in trap and other igneous rocks, forming often veins of several feet in thickness and miles in extent. It is mined for mixing with white paint. For this purpose it is ground to powder, and this is washed with dilute sulphuric acid, by which more or less of oxide of iron is dissolved out, and its color thus improved. The natural sulphate is called *heavy spar,* on account of its great weight, which is often as high as 4·4 or 4·8 (sp. gr.)

Sulphate of baryta is not sensibly soluble in water,* or in any dilute acid. Hot sulphuric acid dissolves a little, but the greater part separates again on cooling. Before the blowpipe it strongly decrepitates, and melts into a white enamel, which, in the course of ten or twelve minutes falls

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* This salt requires for its solution 43,000 parts of cold water. It is not much more soluble in hot or acidulated water.

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229. Write the symbol of the protoxide of barium. What are some of the properties of this oxide? Mention some of the properties of the hydrate. Write and explain the formula for the hydrate. In this formula why are not HO and 9HO united? What is the principal use of hydrate of baryta?

230. Write and explain the formula for chloride of barium. Mention some of its properties.

231. Write and explain the symbol of sulphate of baryta. How does this salt occur in nature? For what purpose is it employed? Why is the natural sulphate called heavy-spar? State some of the properties of this salt.

to powder. By this treatment it is partially converted into sulphuret, and, if applied to the tongue, will give a taste like that of putrid eggs, which arises from the formation of sulphuretted hydrogen. On account of the great insolubility of this salt, it is not poisonous.

232. *Nitrate of baryta*, BaO, NO_5. The nitrate of baryta crystalizes in translucent, white, octahedrons, which are anhydrous. It requires for solution, 8 parts of cold, and 3 parts of boiling water. It is much less soluble in dilute nitric acid than in pure water, and does not dissolve at all in concentrated nitric acid. It is therefore precipitated from its solutions by nitric acid. Nitrate of baryta is used to give a green color to fire-works.

233. Solutions of salts of barium are constantly kept in the laboratory as chemical tests. The nitrate and chloride are used to precipitate sulphuric acid from its solution. The hydrate of baryta is used to effect the separation of the alkalies from the other bases, which it does by its greater affinity for these bases. It is also used to separate carbonic acid from certain gaseous mixtures. The *soluble* salts of baryta are poisonous.

STRONTIUM, 2+. 44. Sr.

234. Strontium may be obtained from its oxide by means similar to those employed in procuring barium. It is a silver-white metal, with less lustre than barium. It is ductile, and decomposes water at common temperatures, and oxidizes rapidly in the air.

Protoxide of strontium, strontia, SrO. This oxide resembles in every respect the protoxide of barium, or baryta. Like that substance, it slakes with a great elevation of temperature when mixed with water. It is less caustic than potash, soda, or baryta. A hot saturated solution on cooling deposits crystals which contain 10 eq. of water. The hydrate has a strong attraction for carbonic acid.

Chloride of strontium, $SrCl$, crystalizes in long six-sided, colorless needles, or prisms, which contain 9 eq. of water, and are slightly deliquescent. They are soluble in 2 parts of cold, and in all proportions of boiling water. They are also dissolved in 24 parts of cold, and in 19 parts of hot alco-

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232. Write and explain the symbol of nitrate of baryta. State some of its properties.

233. For what purpose are the solutions of salts of baryta employed in the laboratory? What salts of baryta are poisonous?

234. Write the specific gravity, combining number, and symbol of strontium.

hol. This salt is used by pyrotechnists in the composition called the fire cloud.

Nitrate of strontia, SrO, NO_5, crystalizes in anhydrous octahedrons, which are transparent and colorless. They require for solution 5 parts of cold and 1 part of boiling water. They deflagrate slightly on charcoal, and give a red flame.

The salts of strontia, which are soluble, give a fine rose-red, or crimson, color to the flame of burning bodies. For this purpose they are used in theatrical exhibitions, and in fireworks. They are detected by the crimson flame which they give to burning alcohol.

Calcium, 2+. 20. Ca.

235. Calcium is a silver-white metal, solid at the ordinary temperatures. It oxidizes rapidly in the air, and inflames when heated. It decomposes water.

Protoxide of calcium, lime, CaO. Lime is obtained by igniting chalk or other kinds of limestone. If a piece of chalk be exposed to the blowpipe flame, it will become much lighter, and will no longer effervesce with acids. It has lost its carbonic acid, and is now lime. If a portion of it be placed on moistened red litmus-paper, it causes blue spots; it has, therefore, an alkaline reaction, which the chalk had not.

To obtain lime absolutely pure, it must be made by igniting to whiteness, in a platinum crucible, an artificial carbonate of lime, procured by precipitation from nitrate of lime, by carbonate of ammonia.

CaO, NO^5=nitrate of lime.
NH_3, CO^2=carbonate of ammonia.
By double exchange.
CaO, CO_2=CARBONATE OF LIME, insoluble salt.
(precipitated from solution.)
NH_3, NO_5=nitrate of ammonia, soluble salt.
(remains in solution.)

Pure lime is a brittle, white, earthy solid, often of consid-

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How may this metal be obtained? State some of its properties. Write and explain the symbol of strontia. What oxide does strontia resemble? What are some of its properties? Write the symbol of chloride of strontium. State some of its properties. Write the symbol of nitrate of strontia. State its properties. How are the salts of strontia detected?

235. Write the specific gravity, combining number, and symbol of calcium. Mention some of the properties of this metal. Write the symbol of lime. How

erable hardness. It is quite infusible, and phosphoresces or emits a pale white light at a high temperature. When moistened with water it slakes with great violence, evolving heat, and crumbling to a soft, white, bulky powder, which is a hydrate containing a single equivalent of water. The latter can be again expelled by a red heat. When slaked, even with ice, lime is raised to a temperature of 212°, and the steam, as it rises, carries with it a large quantity of lime in a state of minute division. When exposed to the air, it also falls into powder, in consequence of absorbing moisture from the atmosphere. The hydrate is soluble in water, though far less so than either the hydrate of baryta or of strontia. Warm water dissolves less lime than cold water.

Hydrate of lime has been obtained in thin, delicate crystals, which are transparent, regular, six-sided prisms. These are formed by evaporation under the receiver of the air-pump, or by placing a vessel containing lime-water, and another containing sulphuric acid, under a glass jar. The sulphuric acid absorbs the moisture from the air above the lime-water, and thus hastens its evaporation. The acid is renewed as often as it becomes saturated with moisture.

Lime-water has a strong alkaline reaction, a nauseous taste, and, when exposed to the air, becomes instantly covered with a pellicle of carbonate, by absorption of carbonic acid from the air. It must, therefore, be kept in closely stopped vessels. It is used, like baryta-water, as a test for carbonic acid. It is also of great use in medicine.

When slaked and made into mortar, lime gradually absorbs carbonic acid from the atmosphere, and is converted into carbonate of lime, or limestone; but a great length of time usually elapses before this conversion is complete. Under favorable circumstances, mortar acquires extreme hardness with age. Lime cements, which resist the action of water, contain clay. A water cement may be made by burning an intimate mixture of chalk with one-fifth clay. When this is ground to powder and mixed with water, solidification speedily ensues, and the cement in this condition is unaffected by water.

Lime is of great importance in agriculture. Many plants, as peas, clover, tobacco, &c. flourish only in a soil containing lime. *The ash* of these plants always contains more than half its weight of lime salts. Lime promotes the decay of

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is lime obtained? How is it prepared in a state of absolute purity? Write out and explain the diagram. State some of the properties of lime;—lime-water. For what is lime-water used? Why does mortar harden with age? What vegetable matter in the soil and accomplishes many other important purposes, as the destruction of certain hurtful compounds of iron in marsh and peat lands.

The caustic properties of lime render it serviceable in tanning. Skins soaked for a few days in lime-water, are easily freed from their hair; they are then thrown into a tan pit.

Lime is generally found in spring and well water; hence these waters are called *hard*, because lime decomposes the soap, taking its acid* and setting free the fatty matter of the soap.

When ignited, lime gives out an intense light, and hence, in the *Drummond light*, a mixed stream of oxygen and hydrogen (183.) is made to fall on a cylinder of lime. This cylinder revolves slowly, so that it consumes more equally by the flame of oxygen and hydrogen.

236. *Chloride of calcium*, CaCl, is usually prepared by dissolving marble in hydrochloric acid, or as a by-product in several chemical manufactures. The salt separates from a strong solution in regular, six-sided prisms, which are colorless, and exceedingly deliquescent. These crystals contain six equivalents of water. By heat the water is expelled, and by a temperature of strong ignition the salt is fused.

Anhydrous chloride of calcium dissolves in water with the evolution of heat; but the crystalized salt produces cold by solution. In forming freezing mixtures, the crystals are reduced to powder, and mixed with snow or powdered ice. In a fused condition the chloride is of great use in drying gases, for which purpose the gases are passed slowly through tubes filled with fragments of the salt. A tube thus prepared is represented in Fig. 81. 100 parts of chloride of calcium in powder, exposed to an atmosphere saturated with moisture, absorb 124 parts of water in 96 days; a quantity greater than that which is required for complete deliquescence.† Chloride of calcium is freely sol-

Fig. 81.

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*This will be explained more fully hereafter.

†For the mode of determining the amount of carbonic acid in the carbonate of lime of bones, and in other forms of carbonate of lime, see organic chemistry, under the article *bones*.

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do lime cements that harden under water contain? What are some of the uses of lime? Why does hard water decompose soap? What are the principal parts of the Drummond light? (183 and 235.)

236. Write the symbol of the chloride of calcium. How is this substance usually prepared? State some of its properties. Explain Fig. 81.

uble in alcohol, and forms with anhydrous alcohol a crystalizable compound.

237. *Sulphate of lime, gypsum, selenite,* CaO, SO_3. Native sulphate of lime in a crystaline state, containing 2 eq. of water, is found in considerable abundance in some localities. When melted it is rendered anhydrous. It is often associated with rock-salt, and is sometimes met with in the anhydrous state. When regularly crystalized, it is termed selenite. In a pure state it may be obtained from a moderately concentrated solution of chloride of calcium, by precipitation with sulphuric acid. It is soluble in about 500 parts of cold water, and its solubility is a little increased by heat; it is precipitated from its solution by alcohol. When a large quantity of sulphuric acid is poured upon a mass of quicklime, the whole becomes red hot.

Gypsum is largely employed in making casts of statues and medals, and also for moulds in porcelain and earthen-ware manufactures, and for other applications. It is exposed to heat in an oven when the temperature does not exceed 260°, and when the water of crystalization is thus expelled, it is reduced to a fine powder. When this powder is mixed with water, it solidifies after a short time, forming again the hydrate. If, however, the gypsum has been overheated, this effect does not take place. Artificial colored marbles are frequently prepared by inserting pieces of natural stone in a soft stucco of this substance, and polishing the surface when the cement has become hard. Sulphate of lime is one of the most common impurities of spring water (219.)

Gypsum has been long and extensively applied to the land as a manure. It is especially useful to leguminous plants, as beans, peas, &c. (p. 172.) These plants not only absorb the lime, but also the sulphur of the sulphuric acid. Gypsum has also a beneficial effect on the growth of plants, as it fixes in the soil the carbonate of ammonia contained in the air and in rain-water. This effect is produced by a double exchange,—the sulphate of lime and carbonate of ammonia becoming carbonate of lime and sulphate of ammonia.

238. *Carbonate of lime, chalk, limestone, marble,* CaO, CO_2. Carbonate of lime forms rocky beds of immense extent and

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237. Write the symbol of sulphate of lime. What is the principal source of sulphate of lime? Mention some of its properties. How is it prepared in a pure state? For what purposes is gypsum used? In what respects is it useful as a manure?

thickness in almost every part of the world. These beds are, however, usually more or less contaminated with oxide of iron, clay, and organic matter. The greatest diversity of texture and appearance exists in these beds of limestone, arising, in a great measure, from changes to which they have been subjected since their formation. The most ancient and highly crystaline limestones are destitute of visible organic remains, while those of more recent origin are often entirely made up of fossil shells. Sometimes these are of such a nature as to show that the animal inhabited fresh water, but generally they are the shells and coral of marine animals. Cavities in limestones and other rocks are very often lined with magnificent crystals of carbonate of lime, or calcareous spar, which have evidently been deposited from a watery solution. These crystals have a greater variety of form and aspect than those of any other substance, except, perhaps, the crystals of snow (122.) Although not sensibly soluble in pure water, carbonate of lime is freely taken up when the water contains carbonic acid (p. 102.) Almost all natural waters, therefore, contain this substance dissolved by the carbonic acid, which is always present in these waters. This is particularly the case in limestone districts. Boilers in which such water is heated, speedily become lined with a thick incrustation of carbonate of lime.

Lithographic stones are made of a fine compact limestone. They are covered with wax, grease, or varnish, and through this coating the design is traced. A weak solution of nitric acid is afterwards applied to the stone, and the lime dissolves in those places which are unprotected; the other places accordingly remain raised, and, when the wax is dissolved off, the design may be transferred by the press as from other plates.

239. *Fluoride of calcium, fluor spar,* CaF, occurs beautifully crystalized in various colors, in lead veins, the crystals having commonly the cubic, but sometimes the octahedral form. They always *cleave* parallel to the faces of an octahedron. A small proportion of the earth of bones (a few thousandths,) consists of fluoride of calcium; a somewhat larger proportion is found in the enamel of teeth; and a still larger quantity is contained in *fossil* bones. It is insolu-

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238. Write the symbol of carbonate of lime How does carbonate of lime occur? What is said of these beds of limestone?—solubility of carbonate of lime? Of what are lithographic stones made? How are engravings made on these stones?

239. Write the symbol of fluoride of calcium. How does this substance oc-

ble in pure water, but like the other insoluble salts of lime, it is dissolved, to a small extent, in water containing carbonic acid.

Some varieties of fluor spar, when heated, emit a green, red, or yellow light. By sulphuric acid it is decomposed with evolution of hydrofluoric acid (165.)

240. *Chloride of lime, bleaching powder*, CaO, ClO. Chloride of lime is formed when chlorine gas is gradually added to lime slightly moist, and kept cool. It is a soft white powder, easily soluble in about 10 parts of water, giving a highly alkaline solution, which bleaches freely.

The use of chloride of lime, as a disinfectant, depends on the action of the carbonic acid of the atmosphere, which gradually expels the chlorine gas, and converts the lime into the carbonate. After a *solution* of chloride of lime becomes in this way covered with a crust of carbonate, the action entirely changes, the chloride of lime gives off pure oxygen, and becomes converted into chloride of calcium (Ca Cl.)

241. The soluble salts of lime are instantly detected by oxalic acid, or an oxalate in solution, which gives a dense white precipitate of oxalate of lime. This is an exceedingly characteristic test.

MAGNESIUM, 1+. 13. Mg.

242. Magnesium is a silver-white metal, with a high lustre. It is very ductile, and capable of being beaten out into thin leaves. It fuses at a low heat, and when heated in small pieces in the air, it burns with a most vivid light, and a lively emission of sparks, and becomes converted into magnesia, which is the only oxide. Cold water, previously freed from air by boiling, has no effect on magnesium. Acidulated water dissolves it readily, evolving hydrogen. Sulphuric acid is decomposed by magnesium giving off sulphurous acid; cold nitric acid gives off binoxide of nitrogen. This metal crystalizes in octahedrons.

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cur? In what parts of the animal frame is fluoride of calcium found? What is said of its solubility? What other properties of fluor spar are mentioned?

240. Write the symbol of chloride of lime. How is it formed? Mention some of its properties. Upon what does its use as a disinfectant depend? What is the action after the chloride of lime solution becomes covered with a crust of carbonate of lime?

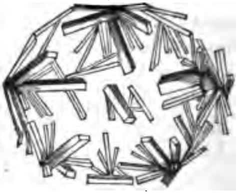
241. How are the soluble salts of lime detected?

242. Write the specific gravity, combining number, and symbol of magnesium. Mention some of its properties.

243. *Magnesia, calcined magnesia*, MgO. Magnesia is a soft, white, tasteless substance, which slowly attracts moisture and carbonic acid from the atmosphere, and unites quietly with water to form the hydrate. In this respect it differs from the hydrate of lime, baryta, and strontia. It possesses a very small degree of solubility, and, like lime, is less soluble in hot than in cold water, requiring about 50,000 parts of water at 60°, and 36,000 parts at 212°. Its alkaline reaction with test-paper is feeble, and may be observed by placing a small portion in a moistened state upon test-paper. It, however, neutralizes acids in the most complete manner.

244. *Sulphate of magnesia, Epsom salt*, $MgO, SO_3, + 7HO$, occurs in sea-water, and in the water of many mineral springs. It also occurs crystalized in long, slender, prismatic crystals (see Fig 82), or as an efflorescence on certain rocks and soils which contain magnesia, and a sulphate or sulphuret. In the United States it is found abundantly in the great caverns west of the Alleghany Mountains. In one of these caves, near Corydon, in Indiana, it forms a stratum on the bottom several inches deep. It also appears on the walls of the cavern, and, if it be removed, acicular crystals will again appear in a few weeks. It is now manufactured in large quantities, by acting on magnesian limestone with sulphuric acid, which produces a mixture of sulphate of lime and sulphate of magnesia. The sulphate of magnesia being soluble, is easily removed by filtration from the sulphate of lime, which is nearly insoluble (237). From a hot saturated solution, this salt crystalizes beautifully in four-sided rectangular prisms. This crystalization is represented in Fig. 82. This salt may also be crystalized on a slip of glass, as described on p. 166. The crystals of sulphate of magnesia are soluble in an equal weight of water at 60°, and in a still smaller quantity at 212°. They have a nauseous bitter taste. It is exceedingly valuable in medicine, as a mild and safe cathartic. By heat, 6 eq. of water are easily driven off, but the seventh is firmly retained.

Fig. 82.



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243. Write the symbol of magnesia. State some of its properties.

244. Write the symbol of sulphate of magnesia. How does this salt occur? How is it now manufactured? What is the form of its crystals? Explain Fig. 82. State some of the properties of sulphate of magnesia.

245. *Carbonate of magnesia,* MgO, CO_2, is found native in magnesian rocks, and is formed artificially by decomposing any of the soluble salts of magnesia by an alkaline carbonate. It is insoluble in water, but, like carbonate of lime, (238.) dissolves in a solution of carbonic acid. When stirred up with water, it manifests a slight alkaline reaction. When this solution is allowed to evaporate spontaneously, small prismatic crystals are deposited, which consist of carbonate of magnesia, with 3 eq. of water. In dry air they effloresce and lose 2 eq. of water. This salt has important uses in medicine.

246. *Silicates of magnesia.* The following natural compounds belong to this class; *steatite,* or *soap-stone,* $5 (MgO, SiO_3)+2HO$; *meerschaum,* MgO, SiO_3+HO. Meerschaum is found in various parts of Europe, chiefly in Greece and Turkey. It is a very porous substance when baked, and is therefore used in the manufacture of pipe-bowls, in which form it often comes to this country. By its porosity it absorbs a noxious oil that is produced in smoking tobacco, while its hardness is so great that it is not easily broken like clay-pipes. *Chrysolite,* $6 MgO, 4SiO_3+3HO$, is a crystaline silicate of magnesia, sometimes employed for ornamental purposes. A portion of magnesia is sometimes replaced by protoxide of iron, which communicates a green color. *Serpentine* is a combination of a silicate and hydrate of magnesia. *Jade* is a silicate of magnesia combined with silicate of alumina. Its green color is owing to oxide of chromium, which it contains. *Augite* and *hornblende* are essentially double silicates of magnesia and lime. The magnesia is also more or less replaced by protoxide of iron.

247. The salts of magnesia are known by a white crystalline precipitate, which they form with the soluble phosphates, especially with phosphate of soda, or by the precipitate formed with ammonia.

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245. Write the symbol of carbonate of magnesia. Where is this salt found? State some of its properties.

246. Mention some of the silicates of magnesia.

247. How are the salts of magnesia detected? How are the metals of this group distinguished from those of the first group? (202.) What are the peculiar properties of the metals of this group? (202.)

GROUP THIRD.

ALUMINIUM, com. num. 14. symbol Al.

248. Aluminium is obtained in the form of a gray powder, resembling finely divided platinum, with shining tin-white points scattered among the powder. The whole may be rendered tin-white by burnishing. It may be compressed in an agate mortar into larger scales, having the perfect metallic lustre.

Aluminium is fusible with great difficulty. When heated to redness in the air it burns brightly. In oxygen its combustion is so brilliant that the eye can hardly endure it, and so great a degree of heat is produced that the alumina formed by the combination is partially fused.

249. *Alumina, sesquioxide of aluminium*, Al_2O_3, is prepared by mixing alum (sulphate of alumina), with ammonia. Alumina and sulphate of ammonia are produced. The latter being soluble, remains in the solution, while the alumina being insoluble is precipitated in an extremely bulky, white, gelatinous precipitate. In this form it is a hydrate of alumina. By remaining in the air it dries, and its volume becomes reduced to a few hundredths of the bulk of the humid mass. To render it pure, the hydrate is washed. It is then dried and ignited to whiteness. Thus obtained, alumina is white and friable. It has no taste, but adheres to the tongue. It is very little acted on by acids. When, however, the hydrate is dried in the air, or by a gentle heat, without ignition, it dissolves freely in dilute acids, and in caustic potash or soda. From these solutions it is precipitated by sal ammoniac. It is highly hygrometic, condensing about 15 per cent. of moisture from the atmosphere in damp weather. It is fusible before the oxy-hydrogen blowpipe. The ruby and sapphire are transparent varieties of a mineral called *corundum*, which consists of nearly pure alumina in a crystalized state, with a little coloring oxide. Emery, used for polishing glass, is a coarse variety of corundum. Alumina is a very feeble base, and its salts have often an acid reaction.

250. *Clay* is a silicate of alumina. If a piece of clay be hollowed out, and some water poured into the cavity, it will

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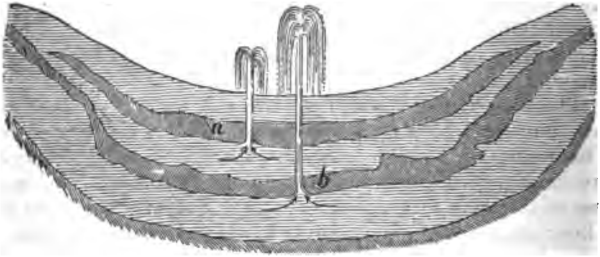
248. Write the combining number and symbol of aluminium. State the properties of this metal.

249. Write the symbol of alumina. How is alumina prepared? What are its properties?

not percolate through it as it does through sand or lime. When beds of clay exist beneath the soil, the rain is unable to penetrate through these beds, and consequently *bogs* and *marshes* are formed. These may be drained by boring holes through the clay beds down to a layer of more loose earth, through which the water can flow. In many places in the interior of the earth, alternate beds of clay and sand are formed, one above the other.(Fig. 83.) If these strata ascend on each side, forming hills, the rain water, as it runs down, must collect between the layers of clay, and rise in them wherever an opening exists, or is formed. From the figure it is obvious that if a boring is made through a second bed, as at *b*, the water may rise higher than in the boring through the first. These artificial fountains are called *Artesian wells*, from the province of Artois, in France, where they were first made.

Fig. 83.



Clay acquires a violet color, when digested with an infusion of logwood for some hours, and renders the solution much more transparent. This it does by its power *of absorbing coloring matter and rendering it insoluble.* It also absorbs unctuous substances, and hence it is much used for extracting grease-spots from wood, paper, &c. It is spread over the surface of these substances, and allowed to remain a day or two in contact with them. A soft variety of clay is used in manufactories, for removing the grease applied to the wool in spinning. That clay has much greater power than sand of imbibing moisture, may be shown by placing

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250. What form of alumina is clay? Mention some of the properties of this substance. Explain Fig. 83. What are Artesian wells? What other properties of clay are mentioned? In what rocks is clay an important constituent? Mention the composition of red pottery ware;—of common white ware. State

half an ounce of dry pulverized clay on a filter, and half an ounce of sand on a second, and pouring water on each. After filtration has ceased, the clay will have gained three-eighths of an ounce, and the sand only one-eighth of an ounce. If the sand is very coarse, its increase of weight will be still less.

Granite, porphyry, trachyte, and other unstratified rocks, consist in great part of clay, or silicate of alumina, which, under peculiar circumstances not well understood, suffer complete decomposition, being converted into a soft friable mass of earthy matter. Decomposed feldspar, one of the constituents of granite, forms the clay which is used in the manufacture of porcelain. This clay is often colored by the oxide of iron.

The common red pottery ware, and also bricks and tiles, are made of common clay, mixed with a portion of sand. The common white ware, stone-ware, tobacco-pipes, &c., are made of fine white clay. Two thin pastes are made, one of this clay mixed with water, another of ground flint. These pastes are then mixed together, and when dry enough to work, they are made into various kinds of ware. These are suffered to dry, so that they may be handled, and then placed in an oven and burnt to hardness. As yet they are without gloss or glaze. This is then put on by a brush, or by dipping the article in a tub of glazing material. The ware is then again burnt. By this last burning, it is *vitrified*. Finally, the colors are laid on and burnt. For common ware, only *one burning* is performed, the three operations above described being performed at once. The patterns upon ordinary porcelain, are first printed upon paper which is attached to the plate or other article before burning. The color adheres permanently to the surface, when heat is applied. The mineral color chiefly employed for this purpose, is oxide of cobalt, which gives blue figures. The oxides of chrome and manganese are also occasionally employed. The steel lustre which is sometimes given to porcelain, is produced by platinum. In the more delicate patterns, the colors are generally mixed with the oil of turpentine, and laid on with a camel's hair brush. When several colors are used, they require various temperatures for their perfection: those colors which bear the highest heat, are first applied, and afterwards, those which are

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the process of glazing. How are the patterns on ordinary porcelain made? What substances are employed to give colored figures? How are these colors usually put on? How is porcelain gilded? Of what is stone-ware made?

brought out at a lower temperature. The gilding of porcelain is generally performed by applying finely divided gold, mixed with gum-water and borax. Upon the application of heat, the gum burns off, and the borax melting the surface, causes the gold to adhere firmly. It is afterwards burnished.

Stoneware is made of clay, containing oxide of iron and a little lime, to which it owes its partial fusibility. The glazing is performed by throwing common salt into the heated furnace. The salt is volatilized and decomposed by the joint agency of the ware and of the vapor of the water always present—

$\mathrm{Na\,Cl}$=chloride of sodium.
HO =water.
By double exchange
NaO =soda.
(fuses into the clay.)
HCl =hydrochloric acid.
(passes off as gas.)

The soda forms a silicate which fuses over the surface of the ware, and gives a thin but excellent glaze.

Earthenware. The finest kind of this ware is made of a white secondary clay, mixed with a considerable quantity of silica. The articles are thoroughly dried and *fired*, after which they are dipped into a readily fusible glaze-mixture, of which oxide of lead is usually an important ingredient, and when dry, reheated to the point of fusion of the mixture. The ornamental designs in blue and other colors, are printed on paper in enamel pigments, mixed with oil, and transferred, while still wet, to the unglazed ware. When the ink becomes dry, the paper is washed off and the glazing completed. The coarser kinds of earthenware are sometimes covered with a whitish opaque glaze, which contains oxides of lead and tin; such glaze is very liable to be attacked by acids, and is dangerous for culinary vessels.

Crucibles are made of clay, free from lime, mixed with sand, or with ground ware of the same kind. Sometimes a mixture of plumbago and clay is used for the same purpose, and powdered coke with earth has been used. Crucibles made in this way, bear rapid changes of temperature without injury.

How is it glazed? Explain the diagram. Of what is the finest kind of earthenware made? How is it glazed? How are the ornamental designs put on? What kind of glaze is sometimes put on coarse earthenware? What is said of this glaze? Of what are crucibles made?

251. Alumina is of great value in the art of dyeing. Although it imparts no coloring matter itself, yet it has the power of *fixing and deepening* the colors of other substances. It is therefore called a mordant, (Latin, *mordeo*, to bite,) because it causes the colors to fasten firmly to the fibre of the cloth.

252. *Constituents of arable land.* If a piece of thoroughly dried clay be exposed to the air for several weeks, it will be found to have gained in weight. This increase in weight is owing to the water, carbonic acid, and ammonia, which it has absorbed. The presence of ammonia may be perceived from the smell when it is triturated with some lime, and a few drops of water (p. 137.) As water, carbonic acid, and ammonia, are the most important means of nourishment to plants, it is evident that clay must enhance the fertility of the soil. The clay most fertilizing in its properties, is that which has stood for years in contact with the air, since, by exposure, soluble salts of lime and potassa have been formed in it. For this reason, bricks or clay-fragments of old buildings, are valued as excellent manure. Hence clay lands, when gently burnt, are rendered more fertile, because the porosity of the clay is thus increased, and consequently its capacity for absorbing air, ammonia, &c. Badly burnt bricks furnish excellent manure.

Clay, or *loam*, and *sand*, form the principal ingredients of arable land. A soil wholly composed of either sand or clay, is wholly unproductive. A clayey soil is too compact and heavy, not allowing the roots of smaller plants particularly, sufficient room to spread. This soil is also so dense as to prevent a free circulation of air. By showers of short duration, it becomes *baked;* a crust forms on its surface, which prevents the water from penetrating into the soil. After long continued rains, it becomes *muddy*, and it then allows the water to evaporate but slowly, and remains for a long time, *wet and cold.* A sandy soil suffers from the opposite disadvantages. It is too porous, and does not hold firmly the roots of plants. It is easily raised up and blown away by the wind, and it permits the rain at first to penetrate too deeply, and afterwards to dry up too rapidly. A clayey soil may therefore be improved by the addition of sand, and a sandy soil by the addition of clay, loam, or marl.

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251. What is said of the use of alumina in dyeing?

252. What experiment illustrates the power of clay to absorb gases? What is the effect of clay upon the soil? What kind of clay is most fertilizing? Why are clay lands improved by burning? Mention the principal ingredients of arable land. Why is a soil composed of either clay or sand unproductive?

253. *Sulphate of alumina*, $Al_2O_3+3SO_3+18HO$. This salt is prepared by saturating dilute sulphuric acid with hydrate of alumina (Al_2O_3) and evaporating. It crystalizes in thin pearly plates, soluble in 2 parts of water. It has a sweet, astringent taste, and an acid reaction. Heated to redness it decomposes, leaving pure alumina.

Sulphate of alumina combines with the sulphates of potash, soda, and ammonia, forming *double salts* of great interest. These salts are called alums. Common alum contains

$$\underset{\text{sulphate of alumina,}}{Al_2O_3, 3SO_3} \quad \underset{\text{sulphate of potash,}}{+KO, SO_3} \quad \underset{\text{24 eq. of water.}}{+24HO.}$$

Alum is therefore a *double* sulphate of alumina and potash, with 24 eq. of water of crystalization. It reddens litmus paper, and dissolves in 18 parts of water at 60°, and in its own weight of boiling water. All the alums are soluble salts, with a sweet astringent taste, and all contain 24 eq. of water of crystalization.

Alum is largely employed in the arts, in preparing skins, dyeing, &c. When it is added to a solution of coloring matter, and the alumina is precipitated by an alkali, all the coloring matter is thrown down with the precipitate, and forms what is called *lake*. The common lake used in water-coloring, is derived from madder treated in this way. Carmine is a lake from cochineal.

CHROMIUM, 6. 28. Cr.

254. The most important ore of chromium, is *chromate of iron*. This is a dark colored substance, totally unlike the beautiful compounds that are formed from it. It is rather abundant, particularly in this country. On account of its great affinity for oxygen, the metal is very difficult to procure. It is whitish-gray, or between tin-white and steel-gray. It is hard and very brittle, breaking when lightly struck with the hammer. It resembles cast iron, is almost infusible, and nearly insoluble in acids. By fusion with nitre, it may be oxidized, but does not change in the air.

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253. Write and explain the symbol of sulphate of alumina. Mention some of its properties. Write and explain the symbol of common alum. What, therefore, is alum? State some of its properties;—some of its uses. What is a lake color?

254. Write the specific gravity, combining number, and symbol of chromium. What is the most important ore of chromium? What is said of this ore? Mention some of the properties of the metal.

255. *Chromic acid*, CrO_3, is formed by adding sulphuric acid to a cold and concentrated solution of bichromate of potash (257.)

$KO, 2CrO_3$=bichromate of potash.
SO_3 =sulphuric acid.
Bring down KO
$2CrO_3$=CHROMIC ACID.
(precipitates from acid solution.)
KO, SO_3=sulphate of potash.
(dissolved in acid solution.)

The chromic acid is deposited from the mixture when cold in ruby-red prisms. The sulphate of potash above the crystals may be turned off, and the chromic acid dried on a porous brick. It must be kept from organic matters, which at once decompose it. For this purpose it should be secured under glass. A little of this acid thrown into alcohol, or ether, produces violent action, and sets fire to the mixture. It is very deliquescent and soluble in water. Its solution is instantly reduced by contact with organic matter.

256. *Chromate of potash*, KO, CrO_3, is formed on a large scale by heating the native chromic iron with nitrate of potash. After the mass has been ignited for a considerable time, the product is treated with water, which dissolves out the chromate of potash, forming a yellow solution. This, by evaporation, deposits anhydrous crystals of the same color. Chromate of potash has an alkaline reaction, and a cool, bitter, and disagreeable taste. It is soluble to a great extent in boiling water, and in two parts of water at 60°. It is insoluble in alcohol.

257. *Bichromate of potash*, $KO, 2CrO_3$, is formed by adding sulphuric acid to a solution of the yellow chromate. One half of the potash is in this way removed to form sulphate of potash, and the bichromate crystalizes by slow evaporation in brilliant red, four-sided, and rectangular tables and prisms. Its powder is reddish-yellow. It decrepitates in the fire, and fuses at a heat considerably below redness, forming a transparent red liquid. It is soluble in ten parts of water, and the solution has a cool, bitter, and metallic taste, and an acid reaction. Both the chromate and the bi-

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255. Write the symbol of chromic acid. How is this acid formed? Explain the diagram. State some of the properties of chromic acid.

266. Write and explain the symbol of chromate of potash. How is this salt formed? State some of its properties.

257. Write and explain the symbol of chromate of potash. State the process of preparing this salt. Mention some of its properties and uses.

chromate of potash, are prepared on a large scale for the use of the calico printer, and for making chrome yellow.

258. *Chromate of lead, chrome yellow,* PbO, CrO_3. This yellow pigment is prepared by precipitation from the nitrate or acetate of lead, by a solution of chromate or bichromate of potash :

PbO, NO_5=nitrate of lead.
KO, CrO_3=chromate of lead.

By double exchange

PbO, CrO_3=CHROMATE OF LEAD, insoluble salt.
[precipitated from solution.]
KO, NO_5 =nitrate of potash, soluble salt.
[remains in solution.]

When boiled with lime-water, the chromate of lead loses half its acid, and a sub-chromate of an orange-red color is left. Still more of the chromic acid is removed by adding chromate of lead to fused nitre, and afterwards dissolving out the soluble salt by water. The product thus obtained is crystaline, and rivals vermillion in beauty of tint. The abstraction of chromic acid, therefore, changes chromate of lead to orange and red, while the addition of this acid changes the yellow chromate of potash to the red bichromate of potash. (See also chromate of silver, under the head of silver.)

259. A salt of chromic acid is detected by the yellow precipitate of chromate of lead and chromate of baryta, which it forms with solutions of baryta and lead. Nitrate of mercury forms a rich cinnabar precipitate with solutions of chromium, nitrate of silver a carmine changing to purple, nitrate of copper a chestnut colored precipitate. The salts of chromic acid may be generally distinguished by their color.

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258. Write the symbol of chromate of lead. State the process of preparing this salt. Explain the diagram. What is the effect of abstracting a portion of chromic acid from the chromate of lead? How is a similar effect produced upon the chromate of potash ?

259. How is chromic acid detected ? How are the metals of this group distinguished from those of the preceding groups ? Mention the peculiar properties of the metals of this group.

GROUP FOURTH.

MANGANESE, 8. 28. Mn.

260. Manganese is somewhat abundant in nature in an oxidized state, forming or entering into the composition of several interesting minerals. Traces of this substance are frequently found in the ashes of plants. It is a grayish-white metal, with but little metallic lustre, resembling some varieties of cast iron. It is very soft and easily split, and yet brittle. It is destitute of magnetic properties. When free from iron it oxidizes so readily that it requires to be kept under naptha. It is fusible with great difficulty. Water is not sensibly decomposed by manganese in the cold. Dilute sulphuric acid dissolves it with great energy, evolving hydrogen. It is also oxidized rapidly by other dilute acids.

Manganese forms an immense number of salts. Even the combinations with oxygen alone are very numerous:

Protoxide,	MnO.
Deutoxide,	$Mn_3O_4 = Mn_9O_{12}$.*
Tritoxide,	$Mn_2O_3 = Mn_8O_{12}$.
Peroxide,	$MnO_2 = Mn_6O_{12}$.
Manganic acid,	$MnO_3 = Mn_4O_{12} = Mn_7O_{21}$.
Permanganic acid,	$Mn_2O_7 =$ . . . . Mn_6O_{21}.

261. *Peroxide of manganese, black oxide,* MnO_2, is the most common ore of manganese, and the most important compound. It is found both massive and crystalized. It has a black color, is insoluble in water, and refuses to unite with acids. It is decomposed by hot sulphuric acid, with the evolution of oxygen gas, and by hydrochloric acid, with the evolution of chlorine (135.) This oxide of manganese has considerable importance in commerce, on account of its uses in making chlorine for bleaching, and also as a component of glass (p. 159, 161.)

262. *Manganic acid,* MnO_3, is not found in a free state, nor formed separately. It is produced when an alkali is fused with an oxide of manganese. The alkali causes the

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* This form is adopted to compare the proportion of oxygen and base which these compounds of manganese contain. The proper formulae are those on the left hand.

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260. Write the specific gravity, combining number, and symbol of manganese. In what state is manganese found? Mention some of its properties. What is said of the combinations of manganese?

261. Write the symbol of peroxide of manganese. What is said of this ore of manganese?

manganese to take an additional quantity of oxygen from the air, and by this the oxide is converted into an acid, which unites with and saturates the alkali with which it is fused. When potash is the alkali employed, a manganate of potash is thus formed, in green crystals. These dissolved in water give an emerald-green color to the solution, which almost immediately changes from the absorption of oxygen from the *air*, becoming in quick succession, green, blue, purple, and finally crimson-red. For this reason it has been called the *cameleon mineral.* The last color is due to the presence of permanganic acid, which, like the manganic acid, cannot be separated from its combinations, but forms a salt with potash in beautiful purple crystals.

263. The salts of manganese are easily detected by the blowpipe. With borax, they give an amethystine bead, in the outer flame, and a colorless one in the inner. With carbonate of soda, they give a green bead. This is a more delicate reaction than that with borax.

IRON, 8. 27. Fe.

264. To this most valuable of all the metals, the present civilization of the world, and the progress of the arts and sciences, are owing. It is probable, that its uses were but little known in the earlier periods of society, although we find it mentioned by Moses and the earlier writers of the Bible. Even the Romans, quite late in the history of their empire, employed an alloy of copper and tin in their armor, instead of iron. The amount of iron consumed at the present day, by any nation, indicates very truly its advancement in the arts and sciences.

Iron must, generally, be obtained from its ore, which is found lying in the earth, or imbedded in other rock; gold is found on the surface in the metallic state. The latter may, therefore, be well known in a savage or half-civilized state of society, while the valuable properties of the former are entirely unknown.

In the condition of oxide, iron is almost universally diffused. It constitutes a great part of the common matter of rocks and soils. It is contained in plants, and forms an essential component of the blood of the animal body. As me-

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262. Write the symbol of manganic acid. How is this acid formed? State some of its properties.

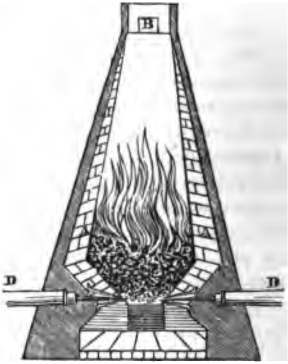
263. How are the salts of manganese detected?

264. Write the specific gravity, combining number, and symbol of iron. What is said of the history of iron? How must iron generally be obtained? How does this metal occur?

tallic iron, it forms at Canaan, in Connecticut, a vein about two inches thick, in mica-slate rock. It frequently, also, enters into the composition of meteorites, or stones, which fall from the air.

265. In reducing iron from its ore, a mixture of several kinds is generally used, because it has been found that the iron is reduced more easily in this way than when only one kind is employed. The mixed ore is piled up along with billets of wood, coal, and other combustibles, in heaps four or five feet high, and many feet in length and breadth. The combustibles are set on fire, and allowed to burn for some days until consumed. This roasting drives off the sulphur and carbonic acid of the ore, and renders it brittle. It is then broken down, and mixed with certain proportions of charcoal, coke, bituminous or anthracite coal, or limestone, and put into a blast furnace. This furnace (Fig. 84.) is about forty or fifty feet high. A A are the sides of the furnace. They are made in such a way, as to be capable of bearing the most intense heat without injury. B is a hole, made at a considerable elevation from the fire, for the introduction of the mixed materials. D D are pipes connected with bellows or other machines for blowing. Beneath the furnace there is a receptacle for the melted metal.

Fig. 84.



Iron ore contains many ingredients which must be melted in order that the iron may flow forth. Among these one of the most important is silica, which is often added when it does not exist in sufficient quantity. Lime is also added, which forms with the silica a glass that melts more readily than either of its constituents (168, 235.) separately, and flows off as slag, bearing with it, to a great extent, the impurities of the iron.

The metal obtained by this process is not pure iron, but a combination of carbon and iron. A hundred weight when

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265. State the process for reducing iron from its ore. Explain Fig. 84. How are the foreign ingredients separated from the ore? What is said of the metal obtained by this process? How is it deprived of its carbon? What are these furnaces usually called when employed for this purpose?

melted from the ore, takes up about four or five pounds of carbon, and likewise some silicon from the silicic acid, aluminium from the clay, and sometimes, also, a trace of sulphur, phosphorus, arsenic, &c. This iron is deprived of its carbon by re-melting in a reverberatory furnace (p. 159), where the fuel does not come in contact with the iron itself. In this furnace, a cheaper fuel than coal may be used, as peat. The iron is constantly stirred in the reverberatory furnaces which, when employed for purifying iron, is generally called a *puddling* furnace.

266. Pure iron has a white color and perfect lustre; commonly, however, its color is a peculiar gray. The crystaline form is probably a cube. In good bar iron, or wire, a fibrous texture may always be observed when the metal has been attacked by rusting, or by the application of an acid, and upon the perfection of this fibre much of its strength and value depends. Iron is the most tenacious of all the metals; a wire of $\frac{1}{36}$ of an inch in diameter bears a weight of 60 pounds. It is very difficult of fusion, and, before becoming liquid, passes through a soft pasty condition. In this state it may be welded (p. 146), which is usually performed by sprinkling sand over the heated metal. This combines with the superficial film of oxide, forming a fusible silicate, which is subsequently forced out from between the pieces of iron by the pressure applied. Clean surfaces of metal are thus presented to each other, and union takes place without difficulty.

In dry air iron does not oxidize at common temperatures. Heated to redness, it becomes covered with a scaly coating of black oxide, and, at a high white heat, burns brilliantly, producing the same substance. In oxygen gas the combustion occurs with still greater ease. The finely divided spongy material, which is formed when the red oxide is reduced by hydrogen (which takes the oxygen to form water), at a heat below redness, takes fire spontaneously in the air. Pure water, free from air and carbonic acid, does not tarnish a surface of polished iron, but the combined agency of free oxygen and moisture, speedily leads to the production of rust, which is a hydrate of the sesquioxide. The rusting of iron is wonderfully promoted by the presence of a little acid vapor. Dilute sulphuric and hydrochloric acids dissolve iron freely with the evolution of hydro-

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266. Mention some of the properties of iron. Why is sand sprinkled over red hot iron in the process of welding? What is said of the relations of iron to oxygen?—magnetism?

gen. Below a red heat iron is strongly magnetic, but at this temperature it loses all traces of magnetism.

267. *Sesquioxide of iron*, Fe_2, O_3. If some iron filings are introduced into a tumbler filled with spring water, the iron will gradually lose it lustre, assume a black color, and become converted into magnetic oxide of iron. If the water is first boiled to expel the air and carbonic acid which it contains, the iron will retain its metallic lustre while it remains beneath the surface; but if the water be poured off, the iron on coming into contact with the air will soon *rust*. This is the sesquioxide of iron with 3 eq. of water which it absorbs from the atmosphere, and which is the cause of the yellow color of rust.

This oxide of iron is found native in the beautiful *specular iron* of Elba, and also in the red and brown *hematites*. It is slightly acted on by the magnet. It is often of a brilliant red, and as *ochre* of various tints, is much used as a pigment. Ammonia precipitates it from its solutions as a bulky red precipitate.

268. *Magnetic oxide, black oxide, loadstone*, FE_3O_4, is one of the most valuable of the iron ores. It is often found in regular octahedral crystals, and is the chief product of the oxidation of iron at high temperatures, in the air and in aqueous vapor. When properly prepared, it is of a deep velvet-black color, without any shade of red (sesquioxide), and attracted by the magnet. It does not form salts.

269. *Protosulphuret of iron*, FeS, is a blackish, brittle substance, attracted by the magnet. It is constantly used in the laboratory, in the preparation of sulphuretted hydrogen (164.) For this purpose, it is made by throwing into a red hot crucible, a mixture of 2½ parts of sulphur, and 4 parts of iron filings or borings of cast iron. The mixture is generally added in small quantities at a time. It is best to exclude the air as much as possible. The same substance is formed when a bar of white hot iron is brought in contact with a roll of sulphur.

270. *Bisulphuret of iron*, FeS_2, is found in the rocks of every geological age. It is evidently formed in many cases

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267. Write the symbol of the sesquioxide of iron. Why is this called a sesquioxide ? (p. 117.) By what experiment may the action of air and water on iron be illustrated ? In what forms is the sesquioxide of iron found native ?

268. Write the symbol of the black oxide of iron. How does this ore of iron occur ? State some of its properties.

269. Write the symbol of the protosulphate of iron. How is it prepared in the laboratory ? State some of its properties.

270. Write the symbol of the bisulphuret of iron. How does the symbol of

by the gradual deoxidation of sulphate of iron (271), by organic matter. It exists under two allotropic forms, that of yellow iron pyrites, and that of white iron pyrites. The yellow iron pyrites has quite the appearance of brass. It occurs in cubic crystals, is very hard, and not attracted by the magnet. When exposed to heat, a sulphuret, intermediate between the bisulphuret and protosulphuret, is produced. When heated, the bisulphuret of iron gives off fumes of sulphurous acid, and is, therefore, now much used in the manufacture of sulphuric acid (151.)

271. *Protosulphate of iron, green vitriol,* FeO, SO_3+7HO, may be obtained directly, by dissolving iron in dilute sulphuric acid. It is generally prepared, on a very large scale, by contact of air and moisture with common iron pyrites (bisulphuret of iron.) This substance absorbs oxygen from the air and moisture, and becomes the protosulphate. Heaps of the material are exposed to the air until the decomposition is sufficiently advanced, and the salt thus produced is dissolved out by water, and crystalized. It forms beautiful large green crystals, which slowly effloresce and peroxidize in the air. They are soluble in about twice their weight of cold water. Crystals containing 4, and also those containing 2 eq. of water, have been obtained. Green vitriol is much used as the basis of all black dyes and inks, and in the manufacture of Prussian blue. In the arts it is called copperas.

272. Of all the combinations of iron, *steel* is the most important. It is formed by heating pure iron in contact with charcoal, and is a compound of iron, with a small proportion of carbon. In common steel the carbon rarely exceeds 2 per cent. It is made by a process called *cementation*. A suitable furnace is filled with alternate strata of bars of the purest malleable iron and powdered charcoal. Atmospheric air is carefully excluded from the boxes containing the bars, and the whole is kept for several days at a red heat. By this process carbon penetrates and combines with the iron. This is probably effected by the agency of carbonic oxide. The oxygen of the air in the crucible combines with the carbon, to form carbonic oxide, which coming in contact with the

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this sulphuret differ from that of the last? What is said of the bisulphuret of iron?

271. Write and explain the symbol of the protosulphate of iron. How does this symbol differ from that of the sulphurets? How is this salt of iron obtained? Mention some of its properties and uses. What is it called in the arts?

272. By what process is steel formed? In what way is carbon brought from the charcoal to the steel? Why is steel formed in this way called blistered

heated iron, is decomposed, and loses one half of its carbon. It then becomes CO_2, or carbonic acid. It afterwards takes up more carbon, and thus returns to CO, or carbonic oxide, and thus the process is continued, the carbonic oxide acting as a *carrier* from the carbon to the heated iron. The product of this operation is called *blistered* steel, from the blistered and rough appearance of the bars. The texture is afterwards improved and equalized by welding a number of these bars together, and drawing the whole out under a light tilt-hammer.

Steel holds a middle place between cast and wrought iron, both as to the quantity of carbon it contains, and its other properties. Like cast iron, when heated to redness, and plunged into cold water, it becomes hard and brittle ; if cooled somewhat more slowly, it is elastic ; if cooled very slowly, it possesses the properties of bar iron, in being soft, ductile, and malleable. Articles of steel are forged into shape, then hardened, and *tempered* or *let down* by exposure to a proper degree of annealing heat. This is often regulated by the color of the thin film of oxide which appears on the polished surface. Thus a faint straw color appears at about 430°, and this is the proper heat for razors. A full yellow or brown tint, is produced by a temperature of 470° to 490°, and this is used for scissors, pen-knifes, &c. Swords and watch-springs, require to be softer or more elastic, and are heated to about 550° or 560°, or until the surface becomes deep blue. Instead of the test by colors, *metal baths* are now often used, which give greater certainty to this process. When heated to redness, and suddenly plunged into cold water, steel becomes capable of scratching glass.

In *fusibility* also, steel is midway between cast iron and bar iron, being less fusible than cast, but more fusible than wrought iron. Articles of *wrought iron* may be superficially coated with steel by plunging them into melted *cast iron.* The same object may be accomplished more easily, by strewing ferrocyanide of potassium over the hot iron. This is decomposed, and the carbon of the cyanogen is absorbed by the surface of the heated iron, as will be explained more fully hereafter.

Many soils contain a large quantity of the oxide of iron, which, on the surface, and in contact with the air, is in the

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steel ? How is the texture of this steel afterwards improved ? What are the properties of steel compared with those of cast and wrought iron ? How is steel tempered ? What test is now often employed for the temper of steel ? In what other respect is steel midway between cast and wrought iron ? How are

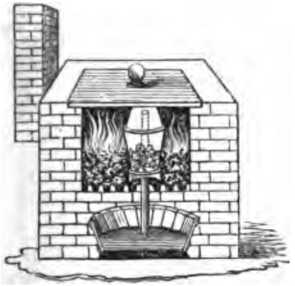
state of the sesquioxide, but beneath the surface is often converted into the first oxide, by the action of the carbon of the organic matter in the earth. This withdraws one third of the oxygen from the sesquioxide to form carbonic acid. In this state the oxide of iron is much more injurious to plants, than as a sesquioxide, on account of its greater solubility. A red irony soil, therefore, should be frequently turned over, especially, if manure has been added to it, and should be kept loose and pervious to the air, that the formation of protoxide of iron may be prevented as much as possible.

273. Many of the compounds of iron are employed in medicine. These preparations are powerfully tonic, raising the pulse, promoting the secretions, and increasing the coloring matter of the blood.

ZINC. 7. 33. Zn.

274. Zinc is not found native, but a peculiar red oxide of zinc abounds at Stirling, New Jersey, and the native carbonate, or *calamine*, is found abundantly in many places.

Fig. 85.



Ores of zinc, like those of iron (265), are first roasted, to drive off the sulphur or carbonic acid with which they are combined. They are then mixed with $\frac{1}{5}$ their weight of charcoal, and placed in a large crucible in a furnace (Fig. 85.) A second crucible is cemented on the first and an iron tube, open at both ends, passes through the bottom of the lower crucible. This tube extends downwards through the bars of the furnace, into a tub of water.

When the heat is applied, the charcoal in the crucible decomposes the ore uniting with its oxygen, to form carbonic oxide, which passes off through the iron tube. The metal, thus reduced, also volatilizes, and passes off with the carbonic oxide; but, while the latter bubbles up through the water beneath, and escapes, the zinc is there condensed and sinks to the bottom.

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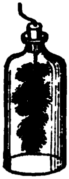
articles coated superficially with steel? What is said of the oxides of iron in the soil?—of the use of iron in medicine?

274. Write the specific gravity, combining number, and symbol of zinc. How does zinc occur? Describe the process for procuring zinc. Explain Fig. 85.

275. Zinc is a bluish-white metal, tough at common temperatures, but very brittle at the point of fusion, which is 773°. At a heat a little above that of boiling water, or from 210° to 300°, it is laminable and ductile; hence, it is drawn out into wire, and rolled into sheets, and after being treated in this manner, or hammered at this temperature, it retains its malleability when cold. When slowly cooled, it crystalizes. By exposure to the air it is oxidized on the surface, but afterwards suffers little change. For this reason iron is coated with zinc, (galvanized iron, 84,) to protect it from the weather. When fused in an open crucible, zinc absorbs oxygen from the air, and forms the white oxide, called the *flowers of zinc*. If the crucible is covered, and heated to full redness, on removing the cover the zinc bursts into a flame, and burns with a brilliant white or greenish light. The combustion is so violent, that the oxide, as it is formed, is carried up into the air. Dilute acids dissolve zinc very readily. By its powerful attraction for oxygen, zinc decomposes a great number of salts and metallic solutions, and precipitates the metal from them. In this manner it precipitates lead from the acetate of lead in the arborescent form (Fig. 86.) This is usually called the zinc tree, although in fact it is composed of lead. Zinc is harder, yet lighter than lead, cheaper than copper, and less liable than iron to be destroyed by air and water. Its uses, therefore, are very numerous and important. It is employed for making nails, gasometers, gas-pipes, gutters for covering roofs of houses, for lining refrigerators, &c.

Fig. 86.



On account of its great combustibility, zinc is sometimes used in fire works. When mixed with nitre and dropped into a red hot crucible, it detonates violently. At a heat of about 770°, zinc melts, and forms a grey film of suboxide, which after a time assumes a yellow color, and is converted into oxide of zinc (ZnO.) As this oxide cools, it passes to a white color, and by this change of color of its oxide, zinc may be distinguished from other metals.

276. All the salts of zinc are poisonous, and excite when

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275. State some of the properties of zinc. In what two ways is galvanized iron protected by the zinc? Ans.—First, the zinc, after being covered with a film of oxide, does not rust as easily as iron. Secondly, by galvanic principles, the iron cannot rust as long as a particle of zinc remains. What experiment illustrates the combustibility of zinc? Explain Fig. 86. What change of color is produced in the oxide of zinc by heat?

276. What is the action of the salts of zinc on the system? What antidotes are employed?

introduced into the stomach violent vomiting. Milk, white of eggs, and coffee, are employed as antidotes.

NICKEL, 9. 30. Ni.

277. This metal is found in considerable abundance, in some of the metal bearing veins of the Hartz mountains, and in a few other localities, chiefly as arseniuret. In this country it has been obtained at Chatham, Ct., and also at Mine la Motte, in Missouri. It has been found as a beautiful green hydrous oxide in Lancaster Co., Pa.

Nickel is almost always found alloyed in masses of meteoric iron. It is a white malleable metal, and takes a high polish. It does not fuse below 3000°. It is not as easily oxidized as iron, since it is but little attacked by dilute acids. It is one of two or three magnetic metals, and magnets may be made of it, nearly as powerful as those of iron. At 660°, it loses its magnetic power. Its chief use is in making German silver, a compound of copper 100 parts, zinc 60, nickel 40.

278. *Sulphate of Nickel*, $NiO, SO_3, + 7HO$, occurs in beautiful green prisms, which contain 7 eq. of water, and dissolve in about 3 parts of cold water. The water of crystalization may be driven off by heat. With the sulphates of potash and ammonia, sulphate of nickel forms beautiful double salts.

COBALT, 8·5. 30. Co.

279. Cobalt, nickel, and iron, have a great similarity, both in their external appearance and in their properties. The two first are constantly found associated in nature, and are obtained from their ores by similar means. Cobalt and nickel have less attraction for oxygen than iron, or do not acquire rust so easily, and are therefore called *nobler* metals. All these metals are magnetic; if pure, however, cobalt would, probably, be found not magnetic. Cobalt is a reddish-white, brittle metal, which melts only at a very high temperature. It is but feebly attacked by dilute hydrochloric and sulphuric acids, and remains in the air unchanged.

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277. Write the specific gravity, combining number, and symbol of nickel. How does this metal occur? State some of its properties. What is the composition of German silver?

278. Write the symbol of sulphate of nickel. Describe this salt.

279. Write the sp. gr., com. num., and sym., of cobalt. What is said of the resemblance between cobalt, nickel, and iron? Why are cobalt and nickel called nobler metals than iron? Mention some of the properties of cobalt.

280. *Protoxide of cobalt*, CoO, is a grayish-pink powder, very soluble in acids. It affords salts of a fine red or pink color. When the cobalt solution is mixed with caustic potash, a beautiful blue precipitate falls, which, when heated, becomes violet, and at length, a dirty red. These alterations in color, are owing to a change in the state of hydration. Both this and the peroxide of cobalt (Co_2O_3,), communicate a splendid blue color to glass. By this reaction with a bead of borax under the blowpipe, oxide of cobalt may be detected. The substance called *smalt*, used as a pigment, consists of glass colored by the oxide of cobalt. Writing paper is prepared with a faint blue tinge, by adding a little of this substance in powder. *Cobalt ultra-marine* is a fine blue color, prepared by mixing 11 parts of freshly precipitated alumina with 2 parts of phosphate or arseniate of cobalt, drying the mixture and slowly heating to redness. By daylight, the color is pure blue; but by artificial light it is violet. *Zaffre* is the roasted cobalt ore, mixed with a quantity of siliceous sand, and reduced to fine powder. It is used in enamel painting. A fine black color is given to glass, by a mixture of the oxides of cobalt, manganese, and iron.

281. *Chloride of Cobalt*, $CoCl$, is easily prepared by dissolving the oxide in hydrochloric acid. It gives a deep rose-red solution, which, when sufficiently strong, deposits hydrated crystals of the same color. When the liquid is evaporated to a very small bulk, it deposits anhydrous crystals which are blue; these also form a red solution on contact with water. A dilute solution of chloride of cobalt forms a blue *sympathetic* ink, which is so pale, that the letters formed with it are invisible, until they are rendered anhydrous by heat, when they appear of a blue color. These soon absorb moisture, and again become invisible. *Green sympathetic* ink is formed by a mixture of the chlorides of cobalt and nickel.

282. Cobalt is precipitated violet-blue, by potash and soda; red, by carbonate of potash and carbonate of soda; green, by yellow prussiate of potash; brownish, by the red prussiate; black, by an alkaline sulphuret; and gray, by the chromate of potash.

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280. Write the symbol of cobalt. State some of its properties. Of what does smalt consist?—cobalt ultra-marine?—zaffre? In what way is a fine black color given to glass?

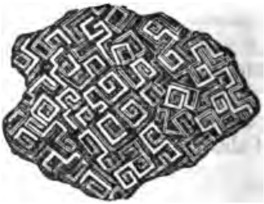
281. Write the symbol of chloride of cobalt. How is this chloride prepared? State some of its properties. How does this group of metals differ from the preceeding groups? (202.) State the peculiar properties of this group.(202.)

FIFTH GROUP.

Bismuth, 10. 71. Bi.

283. Bismuth is obtained from its ore by a very simple process. Its melting point is so low, that all that is necessary is to heat it to about two and a half times the temperature of boiling water, on an inclined plane, when the bismuth melts and flows off below, while the other metals or ores with the *gang*, remain behind unmelted. It is found native, and also in combination with oxygen, arsenic, and sulphur. Native bismuth is found at Monroe, Conn. It is brittle, but may be somewhat extended by careful hammering. Its color is reddish tin-white, and its lustre moderate. It melts at 482°, and crystalizes in cubes. The crystalization of a mass of this metal (Fig. 87.) is very peculiar, and resembles very much a work of art. As it solidifies from fusion, it expands at least $\frac{1}{32}$ part.

Fig. 87.



Nitric acid, somewhat dilute, dissolves bismuth freely. If a plate of pure bismuth is immersed in a solution of caustic potash 1 part, water 5 or 6 parts, and is connected with the positive pole of a galvanic battery (two pairs of Grove's,) of which the negative pole is platinum, the bismuth becomes successively yellow, red, violet, blue, green, and then again colorless, after which, the same series of colors is reproduced, though less strongly. By interrupting the current at the proper time, any color of the series may be fixed. When heated in the air till it boils, bismuth burns with a faint bluish-white flame, and the vapor condenses on colder bodies, forming oxide of bismuth. Fuming nitric acid produces deflagration with melted bismuth, and heats bismuth powder to redness. With other metals, bismuth forms alloys, which melt at a very low temperature. An alloy of equal parts of bismuth, lead, and zinc, is so fusible that it may be melted in moderately hot water. An alloy of bismuth, lead, and tin, is made into spoons, which, when dipped

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283. Write the sp. gr., com. num., and sym. of bismuth. State the process for obtaining bismuth. How does this metal occur? Explain Fig. 87. What other properties of bismuth are mentioned? What is said of the alloys of bis-

into hot tea, melt in the cup; yet the melting points of the constituents of this alloy are comparatively high, that of bismuth being 476°, that of lead 612°, and that of tin 442°, while the alloy melts at the heat of boiling water, or 212°. This fusible metal has lately been obtained in crystals, showing that it is a true chemical compound. An alloy of this kind is sometimes employed as a safety plate in steam boilers. This is melted when the steam, by too great tension within the boiler, increases in heat, and an escape being thus afforded to the steam, an explosion is avoided. As these alloys in their melted state do not burn wood, they are also well adapted for making metallic copies of engraved wooden moulds for calico printing, and block impressions.

Bismuth is detected by the decomposition of its nitrate by water. When a solution of nitrate of bismuth is poured into a large quantity of water, it is immediately decomposed with the production of a copious white precipitate of subnitrate of bismuth. This is owing to the superior basic power of the water which takes *a part* of the nitric acid.

COPPER, 9. 32. Cu.

284. Copper is found in the United States, in masses of immense magnitude. One mass from Lake Superior, weighed over 3000 pounds. It is distinguished from all the other metals, except titanium, by its red color. It receives a considerable lustre in polishing. It is both malleable and ductile, and at the same time very strong and tenacious, so that it may be hammered out into plates, which, even when very thin, still hold firmly together. It has a slightly nauseous taste, and emits a disagreeable smell when rubbed. The use of copper for galvanic purposes, as in telegraph wire, and in the construction of the helices for the battery, is owing to its great power of conducting electricity, to the ease with which it is bent and wound, and to the fact that it is less liable to rust than iron. In dry air, copper undergoes no change, but by a moist air, it becomes covered with a strongly adherent green crust, consisting, in a great measure, of carbonate. Sheet copper is employed for sheathing ships, for roofing towers and other buildings, as it is not so liable to rust as iron. Copper plate engravings are preferred

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muth? To what use are these alloys sometimes applied? How is bismuth detected?

284. Write the sp. gr., com. num., and sym. of copper. How does this metal occur? What are some of its properties? To what is the value of copper for

on account of their durability. For the same reason, copper is employed for the rollers of print works. It quickly oxidizes, when heated to redness in the air, and becomes covered with a black scale (black oxide). It does not fuse below 2200°. It is, therefore, excellently adapted for such articles as are to be exposed to a great heat, as for kettles, boilers, moulds for casting, &c.

Dilute sulphuric and hydrochloric acids hardly act on copper; boiling sulphuric acid attacks it with an evolution of sulphurous acid (147). Nitric acid even dilute dissolves it readily. It is stiffened by hammering and rolling, while zinc is rendered malleable by the same process. It is softened by heating and plunging into cold water, while iron is rendered brittle in the same way.

285. Copper is hard and elastic, and therefore sonorous. *Bell-metal* is an alloy of about 3 of copper to 1 of tin. *Chinese gong metal* is 4 of copper to 1 of tin. *Bronze* differs from bell-metal in having less tin. In this the proportion varies from $\frac{1}{6}$ to $\frac{1}{12}$. By the union of copper and zinc, a metal of a great variety of tints and shades of color may be produced. *Brass* consists of 4 of copper to 1 of zinc. A lighter colored brass is formed of copper 2, zinc 1. *Pinchbeck* is made of zinc 1, and copper varying from 4 to 11 or 12. With this great proportion of copper, its color is almost that of gold, and it is, therefore, employed in the manufacture of trinkets and toys, which are intended to resemble gold. Gold and copper form *common* gold; silver and copper, common silver, from which gold and silver articles and coins are made. The copper serves to harden the silver and gold, and to render articles made of these metals more durable.

286. *Protoxide of copper, black oxide,* CuO, is the base of all the blue and green salts of copper. It is most conveniently prepared, by heating to redness nitrate of copper, which suffers complete decomposition, the nitric acid being driven off, and the black oxide remaining.

Black oxide of copper is used in analysis, to determine the amount of hydrogen which the substance under examination contains. For this purpose, a *combustion tube* (Fig. 88.)

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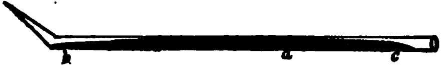
galvanic purposes owing? Why is sheet copper employed for roofing? Why is copper used for engravings? What other properties of copper are mentioned?

285. What is the composition of bell-metal?—gong-metal?—bronze?—brass?—pinchbeck? Why are gold and silver alloyed with copper?

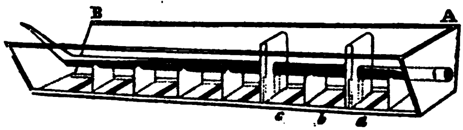
286. Write the symbol of black oxide of copper. How is this oxide prepared?

Fig. 88.



is employed. The oxide is first heated to redness, and while still hot, introduced into the tube till this is about two-thirds full, or to *a*. The proper quantity being thus measured, the black oxide is now turned out of the tube, except a small portion at the end, *b*, and mingled with the substance to be examined. The latter should be previously carefully dried. The *mixture* is then returned to the tube, and this is filled up to *c* with *black oxide*. From *a* to *c*, therefore, is black oxide; from *a* to *b* the mixture, and from *b* to the end of the tube is a small portion of black oxide. After the combustion tube is thus prepared, it is placed in the *furnace*, (Fig. 89). The dark lines, *a*, *b*, *c*, &c. are open spaces through which the air may enter to the fire. Movable partitions are represented within the furnace. Between these and the end of the furnace, at A, the charcoal is piled up, and the fire kindled. When the gas has been expelled from the mixture contained in this portion of the tube, the partition nearest the space, *a*, is moved along towards B, and the space between this and the other partition then filled up with charcoal. Finally, this partition (the one nearest the space *c*), is removed, and the fire then travels along through the charcoal until it reaches the other partition. In this way, the process is continued until the fire gradually passes over the entire length of the combustion tube, and the gaseous contents are all expelled. This tube is usually wrapped with thin sheet brass, to enable it the better to withstand the effects of the heat. Of the gases driven off in this process, *the hydrogen* takes oxygen from the black oxide, and forms watery vapor. This, on leaving the combustion tube, passes through a chloride of calcium tube (236), and is absorbed in this tube. The increased weight of the tube produced by the absorption of the watery vapor, shows the amount of *water* which the gas contained, and $\frac{1}{9}$ part of this is, of course, the hydrogen derived from the body under examination.

Fig. 89.



Explain Fig. 88;—Fig. 89. How is the hydrogen of the substance under examination determined by this arrangement?

287. *Suboxide of copper, red oxide*, Cu_2O, is found native in beautiful octahedral crystals. It is also formed when copper is oxidized by heat, and is the red slag which forms during the calcination and fusion of copper. This oxide communicates to glass a splendid ruby-red color, while the protoxide of copper produces green.

288. *Sulphate of copper, blue vitriol*, CuO, SO_3+5HO. This salt crystalizes in large, beautiful, blue rhombs, which are soluble in 4 parts of cold, and 2 of boiling water. It loses its water by a gentle heat, and falls to a white powder. It is much used in dyeing. With ammonia it forms a dark blue crystaline compound.

289. *Nitrate of copper*, CuO, NO_5+3HO, is made by dissolving copper in nitric acid to saturation. It forms deep blue crystals, very soluble and deliquescent. It is highly corrosive.

Ammonia detects the smallest traces of copper in solution, by the deep violet-blue of the ammoniacal salt of copper which is formed. Iron precipitates it from its solution, as a brilliant red coating. A knife blade is a test for copper, by which it is plated when dipped into any of the solutions of that metal.

LEAD, 11. 104. Pb.

290. Next to iron, lead is the most widely diffused and the cheapest metal. It has been known from the earliest ages of the world. In this country it is found in immense quantities, occurring in numerous states, particularly in that of sulphuret of lead or *galena*. The lead region extends from Wisconsin in the north, to the Red river of Arkansas in the south, and in breadth about 150 miles. Lead is reduced in the same manner as other ores, first by *roasting* the ore to drive off the sulphur, and thus to convert the sulphuret into an oxide. This is then heated with a limited amount of fuel in a flame or blast furnace. The ignited charcoal takes the oxygen of the oxide of lead to form carbonic acid, which flies off and reduces the metal.

A second mode of reducing lead from the sulphuret, consists in heating the ore with a metal which has a greater

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287. Write the symbol of the suboxide of copper. In what form does this oxide occur? How is it formed? To what use is it applied?

288. Write the symbol of sulphate of copper. What is said of this salt?

289. Write the symbol of nitrate of copper. State some of its properties. What tests of copper are mentioned?

290. Write the sp. gr., com. num., and sym. of lead. What is said of the

affinity for sulphur than lead has, and therefore replaces the lead. When iron is used for this purpose, the iron and sulphuret of lead become lead and sulphuret of iron.

Lead is a soft, bluish-white metal, possessing very little elasticity. It has a perceptible taste, and a peculiar smell when rubbed. It is flexible, and may be easily rolled out into plates, and drawn into coarse wire, but this has exceedingly little strength. It melts at 610° or a little above, and, at a white heat, boils and volatilizes. By slow cooling, it may be obtained in octahedral crystals. In the air it oxidizes rapidly, forming a coat of oxide or carbonate, which protects it from further corrosion. When melted it rapidly combines with oxygen from the air, forming either the protoxide or the red oxide, according to the heat. At a moderate heat, lead may be mixed with gold or silver, but when the heat is increased, the lead rises to the surface combined with all the heterogeneous matters. Upon this property of lead is founded the art of refining the precious metals.

Lead does not easily dissolve in dilute acids, except in nitric; with this acid it forms a soluble salt, and when heated with strong sulphuric acid, it dissolves, forming a nearly insoluble sulphate of lead.

291. *Protoxide of lead, litharge, massicot,* PbO. This oxide is a yellow powder, formed by slowly oxidizing lead with heat. It is slightly soluble in water, and the solution is alkaline. At a red heat it melts, and tends to crystalize on cooling. In a melted state it attacks and dissolves siliceous matter with astonishing facility, often penetrating a crucible in a few minutes. It is therefore used in glazing pottery, and in the manufacture of glass. When heated with organic substances it is easily reduced, the hydrogen and carbon of which take its oxygen to form water and carbonic acid.

Red oxide of lead, red lead, Pb_3O_4, is a common pigment formed by exposing melted lead to a temperature of 600° or 700°. It is a brilliant red and extremely heavy powder, decomposed with evolution of oxygen by strong heat. Its composition, therefore, varies with the heat at which it is prepared. It is preferred to litharge in glass making, and is commonly used as a red coloring matter.

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abundance and the forms in which lead occurs. How is lead reduced from its ore? What is the second method? State some of the properties of lead.

291. Write the symbol of the protoxide of lead. What is said of this oxide of lead? For what purposes is it used? Write the symbol of the red oxide of lead. What is said of this oxide?

292. *Carbonate of lead, white lead,* PbO, CO_2, is sometimes found beautifully crystalized in long white needles, accompanying other metallic ores. It is manufactured to an immense extent for the use of the painter. There are three processes in all of which the acetate of lead is first formed, which is afterwards decomposed by carbonic acid. In the first, called the *French process,* carbonic acid is conducted into a solution of basic* acetate of lead. The *excess* of base in this salt of lead, is precipitated by carbonic acid as carbonate of lead or white lead. The acetate of lead thus rendered neutral, will dissolve a fresh quantity of oxide of lead, with which it is digested, and it is afterwards again treated with carbonic acid. This process is repeated until a large quantity of white lead is formed from a small quantity of the acetate. As thus obtained, the carbonate of lead has a dazzling white color, but does not possess the *body* of white lead prepared by the English and Dutch methods.

In the *English method,* oxide of lead (litharge) is mixed with vinegar (acetic acid), to form a paste of acetate of lead. This is then spread upon a stone slab, and exposed to the fumes of burning coke, the carbonic acid of which reduces the basic acetate to the neutral salt, as in the previous case, and precipitates the excess of lead as carbonate of lead.

By the *Dutch method,* a large number of jars containing vinegar are arranged in a building on a layer of stable manure or tan, and rolls of sheet lead are suspended in the jars above the vinegar. The whole is then covered with another layer of stable manure. After several months, the rolls of lead are found to be mostly, if not entirely, converted into carbonate of lead. The *design* of the tan or manure is to produce a high temperature by fermentation, and to furnish carbonic acid to the lead to form carbonate of lead. This heat causes the vinegar to rise in vapor, and attack the lead, forming basic acetate of lead, which is decomposed by the carbonic acid given off in fermentation, and reduced again to the neutral acetate. This a second time attacks the lead, and thus the process is continued as before.

293. Pure water readily attacks lead, and converts it into a hydrated oxide; but spring water, by the action of the sulphates which it almost always contains, forms a coating of

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*Acetate of lead with an *excess of base,* or excess of lead.

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292. Write the symbol of carbonate of lead. How is this substance found? Describe the French process for making white lead. What is said of the lead prepared in this way? Describe the English method;—the Dutch.

insoluble sulphate of lead on the surface, which prevents the lead from further action. It is on this account that leaden cisterns are, in most cases, used with impunity for holding water. If the water were pure, it would be speedily contaminated with lead, and the cistern soon destroyed. Lead tubes for domestic purposes, are unsafe, unless it has been proved by experiment, that the particular water in question does not act on lead. Pipes coated with tin are now made, which obviate all danger from this source.

Lead is cast in sheets by letting it run out of a horizontal slit in a box which is drawn along the table. The Chinese cast it extremely thin in this way, on cloth, for lining chests of tea. A small portion of tin is added to the lead used for this purpose; the thinnest sheets contain the most tin, and are used for enclosing the best teas. Lead is also rolled out to the proper degree of thinness. The melted lead is often poured on a flat stone, and another flat stone brought down suddenly upon it, by which it is pressed out into a thin sheet. The edges are then trimmed, and the sheets soldered together for use.

An alloy of lead 2, and tin 1, constitutes *plumbers' solder*; these proportions reversed, give a more fusible compound called *fine solder*. The lead employed in the manufacture of shot, is combined with a little arsenic, which has the effect to render the drops more perfectly globular.

The test for lead is sulphuric acid. Into a wine glass, half full of water, drop a single drop of sulphuric acid, and add a little nitrate of lead. This small quantity of sulphuric acid, will form a white precipitate of the insoluble sulphate.

MERCURY, 13.5. 100. Hg.*

294. Mercury is the only metal which is liquid at the ordinary temperature. It is occasionally met with in globules disseminated through the native sulphuret. It is sometimes also seen running in small streams at the bottom of the mines. The sulphuret, sometimes called *cinnabar*, is found in considerable quantity in several localities, chiefly in Spain and

*Latin, *hydrargyrum*.

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293. What is the effect of pure water upon lead?—spring water? Why are leaden cisterns in most cases used with impunity to hold water? What is said of lead tubes for domestic purposes? How is lead cast into sheets? State the constituents of plumbers' solder;—fine solder;—shot. What is the test for lead?

294. Write the sp. gr., com. num., and sym. of mercury. What is said of

Carniola. From this ore mercury is obtained by heating it in an iron retort with lime or with scraps of iron, which take away the sulphur, or by roasting it in a furnace from which its fumes are conducted into a large chamber, where they are condensed into metallic mercury and sulphurous acid. Mercury is imported into this country in bottles of hammered iron, containing 60 or 70 pounds each, and in a state of considerable purity. When purchased in smaller quantities, it is sometimes adulterated with tin and lead, which metals it dissolves to some extent, without much loss of fluidity. This admixture may be known by the foul surface the mercury exhibits when shaken in a bottle containing air, and by the globules leaving a train when made to roll upon a table.

Pure mercury is a brilliant metal, of a color nearly silver-white, unchanged by air. It solidifies at—40°, and in this state it is soft and malleable, and may be cut with a knife like gold, silver, and platinum, which are all very soft when pure. At 662° it boils, and yields a transparent, colorless vapor, of great density. This vapor condenses on cold surfaces, in minute, brilliant globules. Even at 60°, a very rare vapor of metallic mercury rises from its surface. When kept in vessels to which air has free access, at a temperature near its boiling point, or above 600°, it gradually becomes converted into a deep-red, crystaline substance, which is the peroxide or red-oxide of mercury. At a dull red heat this oxide is again decomposed into its constituents.

Hydrochloric acid has little or no action on mercury; the same is true of dilute sulphuric acid, but concentrated sulphuric acid, when boiling hot, oxidizes mercury, converting it into a sulphate of the red oxide with the evolution of sulphurous acid. Nitric acid, even dilute and cold, dissolves mercury freely.

295. *Protoxide of mercury, red oxide,* HgO, is prepared in the large way, by heating the nitrate very cautiously, until it is quite decomposed, and a brilliant red, crystaline, powder left. It may also be formed by heating metallic mercury for a long time in a glass vessel nearly closed. It is slightly soluble in water, and its solution has an alkaline reaction and metallic taste. It is highly poisonous.

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this metal? What is the most common ore of mercury? Where is this found? How is metallic mercury obtained from cinnabar? Mention some of the properties of mercury. What is said of the action of acids on mercury?

295. Write the symbol of the protoxide of mercury. How is this substance prepared? State its properties.

296. *Subchloride of mercury, calomel,* Hg_2Cl, is always produced when chlorine comes in contact with mercury at common temperatures. It is sometimes, though rarely, found native, forming *horn quicksilver*, so called from its appearance. From the perchloride (297.) it is distinguished by its insolubility, and by its forming a *black* compound with ammonia, while the perchloride forms a *white* compound. At a temperature below redness, it rises in vapor and sublimes, forming a yellowish-white, crystaline mass. Like the chloride of silver (304.), it is insoluble in cold and dilute, but soluble in strong and boiling hot nitric acid.

297. *Perchloride of mercury, corrosive sublimate*, $HgCl$. When metallic mercury is heated in chlorine, it takes fire and burns, producing this substance. It may also be made by dissolving the red oxide in hot hydrochloric acid, when crystals of corrosive sublimate separate on cooling. The most common method is to sublime a mixture of equal parts of sulphate of mercury and common salt.

The sublimed chloride is a white, transparent, crystaline mass of great density. It melts at 509°, and boils and volatilizes at a somewhat higher temperature. It is soluble in 16 parts of cold and 3 of boiling water, and crystalizes very beautifully, from a hot solution, in long white prisms. Alcohol and ether dissolve it with facility; the latter even withdraws it from a watery solution. Chloride of mercury combines with a great number of other metallic chlorides, forming a series of beautiful double salts. It absorbs ammoniacal gas with great avidity. The aqueous solution is decomposed by light, losing part of its chlorine, and being converted from $HgCl$, to Hg_2Cl (calomel). Many animal and vegetable substances convert corrosive sublimate into calomel. Some substances affect this change slowly, while others, and especially albumen (white of eggs, &c.), produce it in an instant. Hence the solution of the white of eggs is an antidote to this poison.

Like most poisonous substances, corrosive sublimate possesses antiseptic properties in a high degree. For this rea-

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296. Write the symbol of the subchloride of mercury. How is this substance produced? How is it distinguished from the perchloride? State some of its properties.

297. Write the symbol of the perchloride of mercury. How does this symbol differ from that of the last substance? How is the perchloride of mercury formed? Mention some of its properties. What is the antidote for corrosive sublimate? How does albumen render this substance harmless? What other properties of corrosive sublimate are mentioned?

son wood employed in ship building and sleepers for railroads, are sometimes saturated with a solution of it in water. This process is called *kyanizing*. The plants of herbariums, and small animals, may be preserved by being passed through an alcoholic solution of corrosive sublimate.

298. *Iodide of mercury*, HgI. When a solution of iodide of potassium is mixed with perchloride of mercury, a precipitate falls, which is at first yellow, but in a few moments changes to a most brilliant scarlet, and retains this color on drying. This is the neutral iodide of mercury. When suddenly exposed to a high temperature, iodide of mercury becomes bright yellow throughout, and sublimes in minute but brilliant yellow crystals. If touched with a hard body in this state, it instantly becomes red, and the same change happens spontaneously after some time. By a very slow and careful heating, a sublimate of red crystals of a totally different form is obtained, which are permanent. The same change happens with the freshly precipitated iodide; the yellow crystals at first formed, break up and disappear as the salt passes to its red modification.

299. *Sulphuret of mercury, vermillion, cinnabar*, HgS, is formed by passing sulphuretted hydrogen through a solution of corrosive sublimate. The black precipitate which is formed, is sublimed, and becomes dark red and crystaline, but undergoes no change of composition. This substance is most easily produced by subliming an intimate mixture of 6 mercury and 1 sulphur, and reducing to a very fine powder the resulting cinnabar; the beauty of the tint depends very much upon the extent to which the division is carried.

This is the most common ore of the quicksilver mines. When heated in the air it yields metallic mercury and sulphurous acid. It resists the action of caustic alkalies in solution, and is not acted on by strong mineral acids. It is attacked only by aqua-regia.

300. The different salts of mercury have a great variety of colors, according to the amount of oxygen which they contain. Nitric acid, for example, without heat dissolves mercury forming a protoxide (a protonitrate); with heat it forms a peroxide (pernitrate); if ammonia be added to the first solution, a black precipitate is formed; but with the second a

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298. Write the symbol of the iodide of mercury. State the process by which it is prepared. Mention some of its properties.

299. Write the symbol of sulphuret of mercury. How is it prepared? State its properties.

300. What is said of the different salts of mercury? What is the action of

white precipitate occurs. *Chromate of mercury*, formed by adding chromate of potash to nitrate of mercury, has a fine crimson color. Mercury unites with most of the other metals, the tenacity of which, and in most cases the value, is destroyed by the compound. All the salts of mercury volatilize and decompose at a temperature of ignition. If a piece of cinnabar is placed in a tube, and a bright slip of copper also inserted, on heating the cinnabar the mercury will sublime and attach itself to the copper. Those salts of mercury which fail to yield the metal by simple heating, may in all cases be made to do so by adding a little dry carbonate of soda. A drop of any solution of mercury will coat a polished surface of gold with a white amalgam, the instant that the point of a knife is introduced into the solution. The *soluble* compounds of mercury also whiten a slip of copper by depositing metallic mercury on its surface. An ore of mercury may be easily detected by crushing it and throwing some of the powder on a hot plate of iron, or on a hot brick covered with iron filings, and inverting over it a glass of any kind. If any mercury is contained in the mineral, it will rise and attach itself in small globules to the sides of the glass.

SILVER, 10.5. 108. Ag.*

301. The mines of Mexico and the southern Andes, furnish by far the greater part of the silver of commerce. Many mines of this metal are, however, found in Spain, Saxony, and the Hartz mountains. Galena (290.), is also a constant source of silver, and is rarely quite free from this precious metal. Silver often occurs native, and also in combination with sulphur.

Silver has the clearest white of all the metals, and is capable of receiving a lustre surpassed only by polished steel. In malleability and ductility it is inferior only to gold. When pure it is very soft, so that it may be cut with a knife. It does not rust when exposed to air or moisture ; sea air, however, corrodes it on account of the salt which it contains. It is, probably, the best conductor of heat and electricity known.

Pure silver melts at 1873° or at a bright red heat. When

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*Latin, *argentum*.

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heat on the salts of mercury? By what experiment may this be illustrated? What is sometimes added to these salts to reduce the metal? What other tests of mercury are mentioned?

301. Write the sp. gr., com. num., and sym. of silver. Whence is most of the silver of commerce obtained? What other sources of silver are mention-

melted it absorbs oxygen in considerable quantity, amounting sometimes to 22 times its volume. In becoming solid, it parts with the whole of this oxygen, and this produces the granular appearance of silver when hastily cooled. This effect is entirely prevented by a small per centage of copper. At a high heat silver burns with vivid scintillations of a greenish-white color. Tarnished silver is produced by the action of sulphuretted hydrogen, as this metal has a great attraction for sulphur, which it takes from the sulphuretted hydrogen, forming sulphuret of silver. When heated with fusible siliceous matter, as glass, &c., silver oxidizes and stains the glass yellow or orange. This is owing to the formation of a yellow silicate of silver within the glass.

The only pure acids that act on silver are sulphuric and nitric, and by sulphuric acid it is not attacked until heat is applied. Nitric acid is the proper solvent of silver, and its solution furnishes tabular crystals of nitrate of silver. If any gold is contained in the silver, it is left undissolved as a brown powder. If, however, the gold exists in a greater proportion than $\frac{1}{3}$ or $\frac{1}{4}$, it protects the silver from the action of the nitric acid. Hence, it is impossible to reduce by nitric acid an alloy containing this amount of gold. A mixture of 8 sulphuric acid and 1 nitre, will dissolve silver when alloyed with or covering copper, without dissolving the copper. Hence, this mixture is used to remove the silver from old plated ware and from silver coins.

For coinage, and other economical uses, it is necessary to alloy silver with about $\frac{1}{10}$ copper, to render it sufficiently stiff and hard. To determine the proportion of pure silver, the coin may be dissolved in nitric acid, and muriatic acid or a solution of common salt added, which precipitates *chloride of silver*. This precipitate is so bulky and insoluble in water as to impart a cloudiness to a solution of silver diluted a million fold. The amount of precipitate formed will depend upon the amount of silver which the solution contains, and will therefore determine its proportion. As in this experiment hydrochloric acid or chloride of sodium is used to test for silver, so nitrate of silver (302.) is often used in testing

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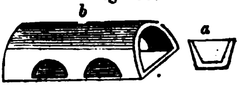
ed ? Mention some of the properties of this metal. What is the cause of the granular appearance of silver when hastily cooled ? How is the tarnishing of silver generally produced ? What color does oxide of silver give to glass ? When gold and silver are alloyed, by what acid may they be separated ? What is the effect of a large proportion of gold in this alloy ? What mixture is used to dissolve silver when alloyed with or covering copper ? What metal is alloyed with silver in coinage ? How may the proportion of pure silver in coin be determined ? What salt of silver is used as a test for chlorine ? By what experifor chlorine in water. This may be illustrated by adding a little salt (chloride of sodium) to a glass of water. When the salt is dissolved, add a little nitrate of silver, and a white cloudy precipitate of chloride of silver is instantly formed. Every hundred grains of this precipitate indicate 42 grains of common salt. Silver is obtained from one of its ores, the sulphuret, on the same principle. This ore is first converted into a chloride of silver, and then reduced from this state to metallic silver. The process is as follows. Common salt is added to the ore, and the whole roasted in a furnace. By this means the sulphur is expelled, and the chloride of sodium unites with the silver, forming *chloride of silver.* This is then put into barrels which revolve on an axis; water is added with oxide of iron and metallic antimony. The whole is agitated for sometime, during which the iron takes the chlorine from the chloride of silver, and reduces the metal. A certain proportion of mercury is then introduced and agitated with the reduced silver. This the mercury dissolves out together with the gold, if there be any, metallic copper, and other substances, forming a fluid amalgam easily separable from the thin mud of earthy matter by subsidence and washing. This amalgam is strained through a strong linen cloth, and the solid portion exposed to heat, by which the remaining mercury is volatilized and the silver is left behind in an impure condition. It is afterwards rendered pure by various processes according to the nature of the substances it is supposed to contain.

A different process is usually employed to obtain silver from galena. The process employed in this case is called *cupellation.* The galena is pulverized and placed with a certain quantity of metallic lead on a little thick cup or cupel, *a*, Fig. 90. This cupel, which is made of bone-ashes, is placed in a muffle, *b*, and the whole is exposed to high heat and *a current of air*, which oxidizes the lead. This is absorbed by the cupel, and carries down with it the other impurities leaving the silver in a brilliant metallic button. The instant the whole of the lead is absorbed, the silver becomes excessively brilliant. This peculiar effect is called *fulguration,* and only takes place the instant the metal has become pure.

Fig. 90.



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ment is this illustrated? Explain the process by which silver is obtained from the sulphuret of silver. Explain Fig. 90. How is cupellation performed on a large scale?

When this process is to be performed on a large scale, the galena is reduced, by roasting and smelting with charcoal, to metallic lead, in which the silver also is contained. This mass is then put into a kind of reverberatory furnace, called the *refining hearth*, which is hollowed out like a kettle. On this hearth it is heated for a day, while a constant current of air is passed over the metal, until all the lead is at last converted into oxide. This oxide melts in the heat, and partly flows off as litharge through a tube, and partly soaks into the porous mixture of clay and lime which has been firmly beaten down on the hearth of the furnace. The silver remains behind in the metallic state. This is rendered still purer by a second heating in clay-basins (smaller cupels), which absorb the remainder of the litharge. If other metals are present in the silver ore, they are likewise oxidized and carried down into the cupel by the litharge.

Many of the *copper ores* also contain silver. These ores are calcined and mixed with a large proportion of lead and then fused and run into moulds. In this form they are called *liquation cakes*. These are placed with layers of charcoal upon an inclined hearth. When the coal is ignited the heat is sufficient to melt the lead but not the copper; the lead, therefore, flows off, and carries with it the silver, while the copper remains behind. This mixture of lead and silver is converted into metallic silver and oxide of lead by cupellation. This process, as well as the last, is much facilitated by the fact that the alloy of silver and lead is more fusible than pure lead. By cooling, therefore, the latter separates from the melted alloy, which is then drawn off. This small portion is cupelled, while the great bulk of the lead is removed for its ordinary uses.

302. *Nitrate of silver*, AgO, NO_5, crystalizes in colorless, transparent, anhydrous tables, which are soluble in an equal weight of cold and in half their weight of boiling water. They are soluble also in alcohol. Nitrate of silver blackens when exposed to the light, more readily if organic matter be present. It is, therefore, frequently employed to dye the hair black, and also bones and ivory, as in chess-men and similar articles, to which it communicates an indelible stain. It also enters into the composition of *indelible ink*. The linen to be marked is previously prepared by an application of solution of carbonate of soda and starch or gum. Let-

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302. Write the symbol of nitrate of silver. What is said of the crystals of this salt? Mention some of the properties of nitrate of silver. State some of the uses to which this salt is applied.

ters are then formed from a solution of 2 drachms of nitrate of silver in an ounce of water, and India ink sufficient to give it the right color. These letters when dry are indelible. This stain is probably metallic silver, which in a state of minute subdivision is black. It may possibly be the suboxide. When ivory is silvered, it is immersed in a dilute solution of nitrate of silver, and left till it has become yellow. It is then taken out and put into a glass of distilled water, and exposed for a short time to the direct rays of the sun. It soon becomes intensely black. It is now taken out of the water and wiped dry. Finally, it is rubbed with leather. The silver is now on the ivory in a metallic state, and may be polished. White marble is figured on the same principle. The surface of the marble is covered with a very thin coating of wax. Through this waxen ground figures or writing are made, and when the marble is made bare in these lines, it is painted over with a camel's-hair brush dipped in nitrate of silver. It is afterwards exposed to a strong sunlight, which decomposes the nitrate of silver, and produces a black stain on the marble wherever the salt touches. If two or three coatings of silver have been thus applied, the reduced silver will take a fine polish. The waxen ground is afterwards dissolved off by spirits of turpentine.

303. *Daguerreotype plates* are copper plates, one surface of which is coated with silver. Oxide of silver is precipitated from a solution of the nitrate by potash. This precipitate is then filtered, washed, and dried, and finally dissolved in ammonia. In the solution thus prepared the copper plate is immersed, after being on one side varnished or otherwise protected. The other side becomes coated with the *oxide of silver* precipitated from the ammoniacal solution. It is then removed from the solution and the ammonia allowed to evaporate. When quite dry, the plate is held over a charcoal fire by the heat from which the oxide of silver is decomposed,* and the metal reduced on the copper in the form of a complete coating. This may be made beautifully bright by polishing with leather and polishing powder, and the plates prepared in this way afford the best surfaces for Daguerreotype pictures.

Clock-faces and barometer plates are silvered in a similar

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*The oxides of the following metals are also reduced by heat; gold, mercury, silver, platinum, palladium, iridium, and rhodium. Hence, these are called *noble metals*, as they are less easily oxidized than the other metals, and more easily restored to their metallic state. For this reason, these metals are often classified together.

303. How are daguerreotype plates prepared? How are clock-faces and ba-

manner. The mixture for this purpose consists of muriate of silver (304.) and moistened cream of tartar. This is rubbed over the plate until it has acquired a complete coat of silver. The cream of tartar (acid tartrate of potash) cleans and brightens the surface, and thus prepares it for receiving the silver. The plate is frequently heated and immersed in distilled water, to wash off the superfluous saline matter.

A *silver tree* (see Fig. 86.) may be made by pouring into a glass globe or decanter, ¼ oz. of nitrate of silver dissolved in about a pint of distilled water. Add ¼ oz. of mercury, and in a short time the silver will be precipitated in the most beautiful arborescent form, which is therefore called *Arbor Dianæ*, or *Tree of Diana*. In this case, the nitric acid of the nitrate of silver has a greater affinity for the mercury than it has for the silver; it therefore deposits the silver and dissolves the mercury. If upon a plate of polished copper, several drops of nitrate of silver be let fall, in a short time a very beautiful precipitate of metallic silver will take place in the arborescent form.

The solid nitrate of silver is melted and cast into sticks or quills. In this form it is called *lunar caustic*, and is used in surgery as a caustic.

304. *Chloride of silver*, $AgCl$. The method by which this salt is prepared has already been mentioned (301.). It is quite insoluble in water and nitric acid, and but slightly dissolved by a large quantity of hydrochloric acid. When heated it melts, and on cooling becomes a grayish, crystaline mass, which cuts like horn; hence, when found native, this is called *horn-silver* (296.). It may be reduced by fusion with twice its weight of carbonate of soda or potash. It is decomposed by light, both in the dry and wet state; *very* slowly if pure, and quickly, if organic matter be present. Also in water with metallic zinc or iron it is reduced, especially if sulphuric acid be added to generate hydrogen. It is soluble with great ease in ammonia. The artificial yellow diamond is made by coloring *white paste* (see experiments on silica), with the chloride of silver, and exposing the whole to a furnace heat.

305. *Ammoniuret of silver, fulminating silver*, is a terribly explosive compound. It explodes by the heat of the hand, by the touch of a tube, and sometimes by a feather. It even

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rometers silvered? How may a silver tree be made? In what form is nitrate of silver used in medicine?

304. Write the symbol of chloride of silver. Mention some of the properties of this salt. What color does this substance impart to glass?

explodes sometimes under the fluid in which it is formed, and of course, while still wet. It is formed by adding to a solution of nitrate of silver a solution of pure lime, as long as a precipitate of the oxide of silver occurs. The liquid is then filtered off, and the precipitate washed with warm water. The powder thus formed is put into a warm place upon paper, that it may be well dried, and when dry, it is put into a wide mouthed phial, containing pure liquid ammonia. The phial is then corked and allowed to remain a whole day, or until the powder becomes black. By this process the powder becomes explosive. The liquid is then poured off and the phial left open in a place where the heat is not greater than 80° or 100°. When dry this powder should remain undisturbed in the phial, as the least friction will cause the whole mass to explode. A watch crystal would answer better for drying the fulminating powder, both on account of the wide surface exposed, and the greater ease with which the powder may be removed when dry. Less injury is done if an explosion occurs.

A similar fulminating powder of gold and platinum may be formed (316 and 322.) The violent and sudden decomposition of these bodies is owing to the feeble attraction which exists between the constituents of the substance, viz: between the oxide of the metal and the ammonia, while the affinity of the oxygen of the oxide and the hydrogen of the ammonia is very powerful. In the explosion, therefore, the metal is reduced, water formed, and nitrogen evolved.

306. *Chromate of silver* is a beautiful carmine color, produced by precipitation from nitrate of silver by chromate of potash. If the chromic acid of the chromate of potash is not in excess, the color of the chromate of silver will be red. If the precipitate is formed while the liquids are hot, it will be reddish-brown.

307. Soluble salts of silver are easily known from the white, curdy, precipitate of chloride of silver, which darkens by exposure to light, and is insoluble in hot nitric acid. This precipitate is produced by the addition of a soluble chloride of any other base. The chloride of lead, and the protochloride of mercury, are precipitated in a similar way, but the latter is easily determined by the tests for mercury, and

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305. What is said of fulminating silver? How is it prepared? To what is the violent and sudden explosion of the fulminates owing?

306. What is said of the chromate of silver?

307. Mention some of the tests for silver. How do the metals of this group differ from those of the preceding groups? How do the oxides and sulphurets of these metals differ from those of the next group?

chloride of lead is soluble to a great extent in boiling water. Solutions of silver are reduced to the metallic state by iron, copper, mercury, and other metals.

The three last metals of this group, palladium, rhodium, and osmium, are usually found associated with platinum, which they also very closely resemble in their properties. They will, therefore, be considered in connection with that metal under the next group.

GROUP SIXTH.

TIN, 7. 59. Sn.*

308. Tin is one of the few metals which were known in the most ancient times. As its ores are often found in the sand by which the soil is covered, it was, therefore, easily obtained. It is also a metal easily smelted. Formerly it was procured principally from the British Islands, and even now these islands, with Malacca, in the East Indies, furnish the purest tin.

The properties which especially characterize tin, and render it a valuable metal, are, its beautiful lustre, its great softness and flexibility, its slight affinity for oxygen, in consequence of which it long retains its brightness in air and water,† its easy fusibility (melting point, 442°,) which renders it peculiarly well adapted for casting and for coating other metals. It is very malleable, and hence it is beaten out into *tin-foil*. Spurious silver-leaf is made of an alloy of tin and zinc, which is hammered out into extremely thin leaves. When bent, tin emits a peculiar crackling sound, which is called the "cry of tin." When heated above its melting point, it oxidizes rapidly, and becomes converted into a whitish powder used in the arts for polishing, under the name of *putty powder*. The common putty used for setting glass, is a compound of carbonate of lime and linseed oil. Tin is

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*Latin, *stannum*.

†This metal, with antimony, arsenic, and chromium, are often arranged into a class next to the noble metals, as their oxides easily lose their oxygen, or form weak bases or acids.

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308. Write the sp. gr., com. num., and sym. of tin. What is said of this metal? Mention some of its properties. State the process by which this metal is ob-

easily attacked by hydrochloric acid with the evolution of hydrogen, and with nitric acid the action is very energetic, producing a white hydrate of the peroxide. It is one of the best conductors of heat and electricity.

In reducing tin from its ore, this is first broken down and roasted, to drive off arsenic and to oxidize the iron which it usually contains. It is then washed or *elutriated* with water, by which process the lighter particles of stone, and to a great extent also, the oxide of iron, are washed away. Finally, it is fused with charcoal in a blast-furnace, and carbonic oxide and metallic tin are obtained; the latter flows off below. Some lead is added to tin for common tin-plate, because pure tin is somewhat brittle and does not adapt itself well to the moulds. In many countries the quantity of lead to be added is regulated by law ($\frac{1}{5}$ to $\frac{1}{6}$). An alloy of this kind is called *proof-tin*, to distinguish it from *grain-tin*, which is tin in its greatest purity.

Tin plate may be beautifully crystalized by heating the plate till the tin is melted, plunging it while hot in water, and finally rubbing it alternately with paper balls, one moistened with dilute aqua-regia, and another with caustic potassa. Both these liquids dissolve the coating of oxide, and lay bare the pure metallic tin surface.

Speculum-metal, a brilliant, almost white, excessively brittle alloy, consists of tin 2, copper 5 parts. When hardened by the admixture of antimony, &c., tin forms *pewter*. Tin plate is sheet iron coated with tin, and copper vessels are often coated with tin on the interior surface to prevent the corrosion of vegetable acids. The use of tin in *bell-metal* (285.) is to render the copper more fluid, and to cause it to assume more perfectly the impression of the mould, as well as to render it more sonorous. *Mosaic gold* (aurum musivum), consists of sulphuret of tin 2, and sal ammoniac 1 part. The sulphuret of tin for this purpose, is formed by combining white oxide of tin with sulphur. Mosaic gold is used by artists to give a beautiful color to bronze.

Tin is not so poisonous as lead or copper, but it is still injurious to health. Acid food and drinks should not be allowed to stand for any considerable length of time in tin or in tinned vessels.

The tests for tin are muriate of gold, which produces a

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tained from its ore. How may tin-plate be crystalized? What is the composition of speculum metal?—pewter?—tin plate? For what purpose is tin used in bell metal? State the composition of mosaic gold. What effects are produced by tin on the system? Mention the tests for tin.

purple precipitate, muriate of platina an orange, ferrocyanate of potash white, corrosive sublimate black, a plate of lead which precipitates metallic tin.

ANTIMONY, 7. 65. Sb.*

309. This metal is derived chiefly from its native sulphuret, which is a rather abundant mineral. The ore is freed from earthy impurities by fusion, and is afterwards decomposed by heating with metallic iron or carbonate of potash, which retains the sulphur. On cooling, the heavy metallic antimony settles to the bottom.

Antimony has a lamellar, crystaline texture, and tin-white color, like bismuth, but without its red tint. It has a high lustre. It is not very hard, but exceedingly brittle and easily reduced to powder. It fuses at 810°. Out of contact of air it volatilizes only at very elevated temperatures, but in a current of air much less heat is required. In a current of hydrogen gas it may be distilled at a white heat, but when covered with a flux, it does not lose more than $\frac{1}{1000}$ of its weight at the strongest white heat. It is not oxidized by the air at common temperatures, but when heated to a white heat in a covered crucible, and then suddenly exposed to the air, it inflames and burns with a white light. The oxide produced during this combustion, is often deposited in beautiful crystals, in the form of small shining needles, of silvery whiteness. By hot hydrochloric acid antimony is dissolved with evolution of hydrogen, and chloride of antimony is formed. Nitric acid oxidizes it to an insoluble white antimonic acid.

Antimony forms brittle alloys with some of the malleable metals. When gold is alloyed with $\frac{1}{200}$ of antimony, the compound is brittle. Even the fumes of antimony in the vicinity of gold render it brittle. The most important of the alloys of antimony is *type-metal*. This is composed of antimony 1, lead 8 to 16, and a small addition of copper. Lead alone is much too soft to be employed for this purpose, but alloyed with antimony it acquires such a degree of hardness, that types cast from it may be used for printing many thousand times without losing their distinctness. Types have, in some instances, been in constant use for half a cen-

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*Latin, *stibium*.

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309. Write the sp. gr., com. num., and sym. of antimony. What is the principal source of this metal? Mention some of its properties? What is said of the alloys of antimony? State the composition of type-metal.—white-metal.

tury without being worn out. Type-metal expands in the act of solidifying, and therefore takes an accurate impression of the mould. When copper is not added, the alloy of antimony and lead is brittle, and on plates of this alloy music is engraved. *White-metal* spoons are formed of tin 100, antimony 8, bismuth 2, and copper 2.

Oxide of antimony, SbO_3, is a pale buff-colored powder, fusible at a red heat, and volatile in a close vessel. In contact with air at a high temperature, it absorbs oxygen and becomes converted into antimonious acid.

Sulphuret of antimony, *crude antimony*, SbS_3, is a lead-gray, brittle substance, having a radiated crystaline texture. It melts even in the flame of a candle, and hence, may be easily obtained from the various rocks with which it is associated. On solidifying after fusion, it becomes filled with cracks, owing to its great contraction. At a strong red heat it boils, and may be distilled without decomposition if the air be excluded. It is sometimes prepared by precipitating a solution of tartar emetic (tartrate of antimony and potash,) with sulphuretted hydrogen. In this case, a sulphuret of potash is also formed, which being soluble, remains in the solution, while the sulphuret of antimony, being insoluble, is precipitated. As thus prepared, the sulphuret of antimony has an *orange color*, which grows darker on drying. It is also prepared by melting together antimony and sulphur. Mixed with nitre, &c., it is easily burnt, and gives a bright white or bluish-white flame. It is, therefore, much used in pyrotechnic compositions.

The soluble compounds of antimony are hostile to life, and the stomach exerts itself to remove all such compounds introduced into it. This is effected by vomiting, and for its use in producing this action of the stomach, antimony has become an important medicine.

The tests for antimony are sulphuretted hydrogen, which gives an orange precipitate, and a plate of iron which precipitates metallic antimony in the form of a black powder.

ARSENIC, 6. 75. As.

310. Metallic arsenic is found native in thick crusts called testaceous arsenic, evidently deposited from sublimation.

Write the symbol of oxide of antimony. State some of its properties. Write the symbol of sulphuret of antimony. Mention its properties. What is its color when precipitated from solution of tartar emetic by sulphuretted hydrogen? For what purpose is it sometimes employed? What are the relations of antimony to medicine? Mention the tests for antimony.

Most of this metal, however, is derived from roasting the natural arseniuret of iron, nickel, and cobalt. The vapors of arsenious acid (311.) given out, are condensed in a long and nearly horizontal chimney, or in a kind of tower of brick-work, divided into numerous chambers. The crude arsenious acid thus produced, is purified by sublimation, and then heated with charcoal in a retort. The charcoal absorbs the oxygen of the acid, and reduces metallic arsenic which sublimes.

Arsenic is a soft, brittle, exceedingly poisonous metal. Its color is tin-white, inclining to a steel-gray. It has a high metallic lustre, and is easily crystalized. When heated it volatilizes without fusion, and, if air be present, oxidizes to arsenious acid. This vapor has the smell of garlic. Arsenic combines with the metals in the same manner as sulphur and phosphorus, which it resembles, especially the latter, in many respects. The combustion of arsenic may be performed by throwing a few grains in powder into a red hot crucible. It bursts into a flame of a bright blue color, and continues to burn until completely consumed or volatilized.

311. *Arsenious acid, white oxide of arsenic,* AsO_3. As commonly obtained, this is a white, glassy-looking substance in brittle masses, with a conchoidal fracture, and shows marks of fusion. When freshly prepared it is transparent, but by keeping, it becomes opaque, at the same time slightly diminishing in density, and acquiring a greater degree of solubility in water. 100 parts of water at 212° dissolve about 11.5 parts of the opaque variety; the larger portion separates on cooling, leaving about 3 parts dissolved. Cold water agitated with arsenious acid takes up a still smaller quantity. Alkalies dissolve this substance freely, forming arsenites which do not crystalize. Hydrochloric acid also readily dissolves it.

Arsenious acid sublimes at 380°, and crystalizes on cooling in brilliant, transparent octahedrons, which are very characteristic. They may be formed for experiment by heating a small quantity in a glass tube. Its vapor is colorless and inodorous, but, if sublimed from charcoal, it gives the peculiar garlic odor of metallic arsenic, for the charcoal takes away the oxygen and reduces the arsenic to the metallic

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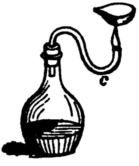
310. Write the sp. gr., com. num., and sym. of arsenic. How does this metal occur? How this is metal usually obtained? Mention some of its properties.

311. Write the symbol of arsenious acid. What are the properties of this substance? What is the best antidote for arsenious acid? In what state is this remedy most effective? How does the red-oxide of iron destroy the poisonous

state. It is almost tasteless with a faint sweetish flavor, which with its color renders it the more dangerous. Most of the metallic poisons give warning by their peculiar taste, but the appearance and taste of arsenious acid is that of a harmless substance. The best antidote for this poison is the hydrate of the red oxide of iron. This remedy is most active when recently prepared and in a gelatinous condition. It forms an insoluble arseniate of the protoxide of iron. Like most other poisonous substances, arsenious acid possesses remarkable antiseptic properties. For this reason the bodies of those who have been poisoned by it are often preserved. In natural history it may be used for the same purposes as corrosive sublimate (297.)

To determine in supposed cases of poisoning, one of the best methods is that called *Marsh's test.* Introduce into a small flask (Fig. 91.) some pieces of zinc and dilute sulphuric acid. Hydrogen will be formed, which will escape through the bent tube *c.* After some time, if the jet of hydrogen be lighted, and a porcelain capsule held over the extremity of the flame, drops of pure water will collect on the bottom of the capsule. In this case the *capsule is not discolored.* If now a piece of wood dipped in any arsenical solution, so that only a little of the solution shall remain adhering to the wood, be introduced into the flask, the flame, after the gas has been rekindled, will present a bluish-white appearance, *and will deposit on the porcelain capsule a smooth black or brown spot* (mirror of arsenic.) This spot is metallic arsenic. The arsenic introduced within the flask combines with hydrogen, forming *arseniuretted hydrogen,* which escapes and burns. When this flame is cooled by the porcelain capsule, the metallic arsenic will not burn at the low temperature thus produced, and is, therefore, deposited on the capsule. Arseniuretted hydrogen is a most poisonous gas. Its fumes should therefore be avoided, as, in several instances, experimenters have lost their lives by this gas.

Fig. 91.



In cases of poisoning, the stomach and its contents are divided into small pieces, and the organic matter destroyed by adding hydrochloric acid and chlorate of potash, or by heating with sulphuric or strong nitric acid, till the mass

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properties of arsenic? What use is sometimes mode of arsenic? Explain Fig. 91. What process is followed in cases of poisoning to detect arsenic?

begins to char, and then draining with water, and filtering the solution. The liquor thus obtained is subjected to Marsh's test. If a black spot is produced, this will indicate arsenic in considerable quantity. If no spot on the porcelain is produced, the tube is then ignited by a spirit-lamp at the point *c*, and a black ring will be formed on the tube a little beyond this point, if arsenic be present. A black spot will also be produced if antimony is present in the solution, but the latter will remain unchanged when a solution of chloride of lime is applied, while the arsenical spots will be dissolved. The bent tube should be made of hard glass, without lead, in order to bear the heat required in this experiment.

312. *Arsenic acid*, AsO_5, is formed by dissolving powdered arsenious acid in hot hydrochloric acid. Nitric acid is added to peroxidize the solution as long as red vapors are produced. The whole is then cautiously evaporated to complete dryness.

The acid thus produced is white and anhydrous. It melts at a low red heat, and after fusion it is colorless, transparent, and glassy. If too strongly heated, it is white and opaque. When put into water it slowly and completely dissolves, giving a highly acid solution, which deposits on evaporation hydrated crystals of arsenic acid. When strongly heated, it is decomposed into arsenious acid and oxygen gas. It is excessively poisonous.

313. There are two principal *sulphurets of arsenic: Realgar*, AsS_2, occurs native, and is formed artificially by heating arsenious acid with a minimum of sulphur. It has a splendid red color, is fusible and volatile, and is employed by the pyrotechnist in making *white fire. Orpiment*, AsS_3, is also a natural product, and is made by fusing arsenious acid with an excess of sulphur, and by precipitation with sulphuretted hydrogen from a solution of the acid. It is a golden-yellow crystaline substance, fusible and volatile by heat. In acid solutions of arsenic, sulphuretted hydrogen produces a splendid yellow precipitate of sulpharsenious acid. Heat promotes the separation of this precipitate.

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312. Write the composition of arsenic acid. How is this substance formed? Mention some of its properties.

313. Write the composition of realgar. How is it prepared? What are its properties? Write the composition of orpiment. How is this substance procured? State its properties.

GOLD, 19·5. 99. Au.*

314. Gold, in small quantities, is a very diffused metal; traces of it are constantly found in the iron pyrites of the most ancient rocks. It is always met with in the metallic state, sometimes beautifully crystalized in the cubic form, associated with quartz, oxide of iron, and other substances, in regular mineral veins. The sands of various rivers have long furnished gold, derived from the crumbling down of rock. Some crystals of native gold from California, are represented in the accompanying figures. In Figs. 93 and 94, is also seen the native gold attached to the crystals, in the form in which usually occurs. Gold ore is crushed and shaken in a suitable apparatus, with water and mercury; the mercury forms an amalgam with the gold, which is separated and afterwards exposed to heat, by which the mercury is distilled, and pure gold left behind.

Fig. 92.

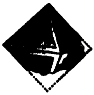


Fig. 93.

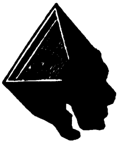
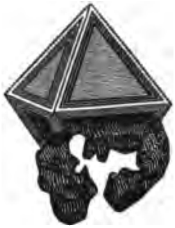


Fig. 94.



To obtain gold from its alloy of silver and copper, it is boiled with concentrated sulphuric acid, which dissolves the silver and copper, and leaves the gold as a brown powder. The gold being separated, the silver is afterwards obtained from the acid solution by adding *more* copper. The greater affinity of the acid for the copper causes it, when saturated with this metal, to leave the silver, which is therefore precipitated. Copper alone remains in the solution, which is poured off and evaporated to form sulphate of copper or blue vitriol.

Pure gold is obtained by solution in aqua-regia and precipitation by a salt of the protoxide of iron, which takes the

* Latin, *aurum*.

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314. Write the sp. gr., com. num., and sym. of gold. What is said of this metal? How is gold obtained? How is it obtained in a pure state?

oxygen from the solution of gold, and reduces the gold to the metallic state. The gold falls down in brown powder, and acquires the metallic lustre by friction.

315. From all other metals gold is distinguished by its *yellow color*, and its extreme *permanence in air and fire*. Even sea-water, which corrodes silver, has no action on gold. Hence, mirrors for light-houses are often coated with a thin film of gold to protect them from the action of the sea-air. Gold is distinguished also by its great malleability, which is such that gold leaf not more than $\frac{1}{282,000}$ of an inch may be beaten out, and a single grain of gold may be extended over 156 sq. in. of surface. So great is its *ductility*, that a grain of gold may be drawn out into 500 feet of wire, and one ounce of gold may be extended 300 miles. Its density is also more than twice that of iron or copper, and nearly twice that of lead. The acids separately do not attack gold, but aqua-regia dissolves it readily. In this case the active agent is chlorine, which exists in a free state in this acid mixture. Solutions of gold are decomposed by hydrogen and sulphurous acid gas. These gases take the oxygen from the oxide of gold in solution, and liberate the gold in the metallic state. There are two oxides of gold, both of which refuse to unite with acids. With chlorine, iodine, sulphur, &c., gold forms two compounds corresponding to those with oxygen. The affinity of gold for oxygen is so weak that solutions of the oxide are decomposed even by light.

Gold melts at 2016°, and, when in fusion, appears of a bright green color. This color is nearly the same that it has when a thin leaf of gold is held up to the light, or when an electrical spark is passed over a strip of gold leaf in a dark room. When intensely ignited by electricity or the oxy-hydrogen blowpipe, gold burns with a greenish-blue flame.

316. *Ammoniuret of gold, fulminating gold*, is prepared by adding ammonia to a concentrated solution of chloride of gold, diluted with about three parts of water. A yellowish brown precipitate is formed, which is collected upon a filter, and carefully dried at the temperature of boiling water. This when dry explodes with terrible violence, but it requires a higher heat (120° to 300°), or a greater degree of friction than fulminating silver. If placed upon a piece of sheet copper, and held over a lamp, it will soon explode, and the

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315. How is it distinguished from all the other metals? What other properties of gold are mentioned? What is said of the compounds of gold?

316. How is fulminating gold prepared? What are its properties?

copper, if not torn, is always indented. Fulminating gold consists of 5 peroxide of gold and 1 ammonia.

317. *Gilding on copper*, is performed by dipping the article into a solution of nitrate of mercury, and then rubbing it with a soft amalgam of gold and mercury. It is then heated to expel the mercury, and burnished. *Gilding on steel* is done either by applying a solution of perchloride of gold in ether, or by roughening the surface of the metal, heating it, and applying gold leaf with a burnisher. *Gilding on wood, &c.*, is done by painting the design to be gilded with varnish, and then applying gold leaf. After the varnish is dry, the gold leaf is rubbed off, except where it was made to adhere by the varnish. Gilding by the galvanic process (p. 58,) is now rapidly superseding many of the other processes. *Gold wash* is a mixture of the oxide of gold with carbonate of soda or potash in excess. Articles cleansed with nitric acid are boiled in this wash, and thus become perfectly covered with a thin film of gold.

The most simple mode of *testing gold*, is to rub some of it off upon a black-flint slate (touch-stone), and apply to the mark nitric acid. If the gold is pure, the yellow streak remains unchanged; but if alloyed, it partly disappears; if only an imitation of gold, it dissolves entirely. The presence of gold in solution may be known by the brown precipitate of metallic gold with protosulphate of iron, which is fusible before the blowpipe into a bead. When added to a solution of protochloride of tin, a purple precipitate is formed, which is a mixture of peroxide of tin and metallic gold (p. 217).

PLATINUM, 21.5. 99. Pt.

318. Crude platinum, a native alloy of platinum, palladium, rhodium, and a little iron, occurs in small grains and rolled in masses, sometimes of considerable size. It is found on the slope of the Ural mountains, in Russia, mixed with gravel and transported minerals. It also occurs in Ceylon, in California, and a few other places. It has never been seen *in place* (in the rock, or in the vein), but the rock to which it belongs is supposed to be serpentine.

Platinum is a white metal, between tin and steel in color, and inferior to silver in lustre. When pure, it is a soft metal,

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317. State the process for gilding on copper;—on steel;—on wood. What process is now generally preferred in gilding? State the composition and mode of using gold wash. Mention some of the tests of gold.

318. Write the sp. gr., com. num., and sym. of platinum. How does this

but usually, owing to impurity, it is quite hard. A very little rhodium or iridium (325, 326.) renders it more gray in color, and much harder. It is exceedingly malleable and ductile (p. 146,) both hot and cold. It is very infusible, melting only by the oxy-hydrogen blowpipe or the galvanic battery. Like iron, it admits of being welded at a high temperature, and in this way it is made into chemical vessels. It dissolves in aqua-regia, and superficially oxidizes with fused hydrate of potash, and the potash enters into combination with the oxide thus formed. *All the easily fusible metals* combine with platinum, and the alloys which they form are quite fusible and easily attacked by acids; hence platinum vessels are ruined when these alloys are formed. Neither these metals nor their ores should be melted in platinum vessels. These vessels also should never be exposed to the action of chlorine, or its compounds, especially when chlorine is disengaged in its nascent state. It is in this state that chlorine renders aqua-regia a solvent for gold and platinum.

319. Platinum is obtained pure by digesting crude platinum in aqua-regia, and adding to the deep brown liquid a solution of chloride of ammonium. This throws down an orange colored precipitate, which is a double chloride of platinum and ammonium. When heated, the chloride of ammonium is driven off, and also the chlorine of the chloride of platinum, and the platinum reduced to the metallic form. In this state it is a dull brown mass called spongy platinum, or *platinum sponge*. This is condensed in steel moulds with heat and pressure to the metallic state, and when compact enough to bear the blows of a hammer, is heated and forged into a bar, which can afterwards be rolled into plates or drawn into wire at pleasure.

Platinum sponge has the power of absorbing several of the gases, and when suspended in a jar of oxygen and hydrogen, it causes the immediate union of the two gases (Fig. 40.) A jet of hydrogen falling upon spongy platinum, will by its rapid combination with the oxygen of the air, ignite the platinum, and afterwards take fire. In the same manner, clean slips of platinum foil, and even gold and palladium will produce the union of oxygen and hydrogen. If into a dry phial of oxygen gas a piece of platinum sponge be

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metal occur? Mention some of its properties. What class of metals combine with platinum?

319. How is platinum obtained pure? What is platinum sponge? How are bars of pure platinum made? Mention some of the properties of platinum sponge;—platinum foil;—red hot platinum. By what experiment is this property of platinum illustrated?

dropped, and the phial be stopped and set aside for several days, the platinum sponge will absorb the oxygen, as may be shown by unstopping the phial beneath water, when the water will rush up into the phial and quite fill it. Platinum sponge will absorb 100 times its bulk of oxygen.

Red hot platinum also decomposes oils, spirits, &c. For this reason a coil of platinum is used in the safety lamp (181.) If a coil of platinum be suspended, while red hot, in a wine glass containing a little alcohol or ether, it will continue to glow, from the action of the vapor which arises from the alcohol or ether. The action is so energetic that frequently the vapor is set on fire. The same experiment may be tried over the wick of a spirit lamp. The lamp should be lighted at first, and blown out when the coil of platinum is ignited. The coil will continue to glow, after the lamp is extinguished, until the whole of the alcohol is exhausted.

320. *Platinum black* is another form of platinum, possessing similar properties to spongy platinum, but in a higher degree. When the galvanic current is passed through a weak solution of chloride of platinum, a black powder of platinum appears at the negative pole. The silver plates in Smee's battery (p. 59,) are platinized in this way.

321. *Bichloride of platinum*, $PlCl_2$, is always formed when platinum is dissolved in aqua-regia. The acid solution yields on evaporation to dryness, a red or brown residue, deliquescent and very soluble in both water and alcohol. The aqueous solution has a pure orange yellow tint. Bichloride of platinum combines to form double salts with a great variety of metallic chlorides.

322. *Ammoniuret of platinum, fulminating platinum*, is prepared in the same manner as fulminating gold, and possesses similar properties. If 2 or 3 grains of either of these fulminating powders be placed upon a cold fire shovel, and the shovel be gradually heated over a slow fire, when the fulminating powder arrives at about 400° of temperature, a most violent explosion will take place. This experiment should be performed in the open air, as the sudden concussion given to the air is very likely to throw down and destroy every-

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320. What is platinum black? In what galvanic battery are the plates platinized?

321. Write the composition of bichloride of platinum. How is this substance prepared? What are its properties?

322. How is fulminating platinum prepared? State the properties of this substance.

thing standing around. The person performing the experiment should retire to some distance after placing the shovel on the fire.

323. Platinum is invaluable to the chemist for crucibles and other vessels exposed to a high heat, or to the action of acids. Large retorts or boilers are made of it, for the use of manufacturers of sulphuric acid, which sometimes hold sixty or seventy gallons. In Russia it has been employed in coinage, for which it is well suited by its great density and hardness. Its value is intermediate between that of gold and silver.

The tests for platinum are the chlorides of potassium and ammonium. These produce yellow crystaline precipitates, which are insoluble in acids, but soluble in an excess of the *precipitants* upon the application of heat.

PALLADIUM, 12. 53. Pd.

324. This very rare metal is usually found associated with platinum. It is also found alloyed with gold and silver in Brazil. It very closely corresponds with platinum in color, appearance, and difficult fusibility. It is also very malleable and ductile. It is a grayish-white metal, fusible by the oxy-hydrogen blowpipe. In density it differs very much from platinum, being only a little heavier than lead. It is also more oxidable than platinum. At a red heat it gains a blue tarnish like steel, which is again reduced at a white heat. In hardness, it is equal to fine steel, and it retains its elasticity and stiffness at a red heat. It suffers no change by exposure to the air. Its proper solvent is aqua-regia, but it is slowly attacked by nitric acid.

The test for palladium is iodide of potassium, which throws down a dark brown precipitate.

RHODIUM, 11. 52. R.

325. Rhodium is a reddish metal, somewhat ductile and extremely hard. When reduced to powder and heated in the air, it becomes oxidized. This takes place to a greater extent when it is fused with nitrate or bisulphate of potash.

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323. What are some of the uses of platinum?—its tests?

324. Write the sp. gr., com. num., and sym. of palladium. How does this metal occur? What are its properties? What is the test for palladium?

325. Write the sp. gr., com. num., and sym. of rhodium. How may this metal be obtained from its alloy with platinum? State its properties.

In the latter case, sulphurous acid is evolved, and a double sulphate of peroxide of rhodium and potassa formed, which dissolves readily in hot water, and yields a yellow solution. The presence of rhodium in the alloy of platinum, &c., may be in this manner detected, and, by repeated fusion, a perfect separation accomplished. In its pure state, rhodium is not attacked by any of the acids ; but if alloyed with other metals, as with platinum, copper, or lead, it is dissolved by aqua-regia. An alloy of steel, with a small quantity of rhodium, is said to possess exceedingly valuable properties.

IRIDIUM, 16. 99. Ir.

326. When obtained pure and fused, iridium is a brittle, very hard, somewhat ductile metal, of pale antimonial whiteness, and having the fracture of cast iron. It is the most infusible of all the metals, being fused with great difficulty before the oxy-hydrogen blowpipe. It is not attacked by any acid, but is oxidized by fusion with nitre, and by ignition in the air. It is apt to fall to powder when burnished, but with care it may be polished, and then resembles platinum. The chief use of iridium is in pointing gold pens, for which purpose it is adapted by its hardness.

OSMIUM, 10. 100. Os.

327. In the most compact state in which this metal can be obtained, it has a bluish-white color, and, although somewhat flexible in thin plates, it is easily reduced to powder. It is neither fusible, nor volatile. When heated to redness it burns, yielding *osmic acid* which volatilizes. *Osmiate of potash* is produced when the metal is fused with nitre. In a finely divided state it is readily oxidized and dissolved by strong nitric acid.

328. In the list of metals now described, many have been omitted which it would have been desirable to describe in a larger work. On the other hand, several have been introduced, not so much on account of their own importance, as from their peculiar and very remarkable properties, and

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326. Write the sp. gr., com. num., and sym. of iridium. What are the properties of this metal ?

327. Write the sp. gr., com. num., and sym. of osmium. State the properties of osmium.

their intimate connection with other metals of the first importance.

The following table includes a list of all the metals, with their specific gravities, combining numbers, and symbols, so far as these have been determined:

Metals.	Sp. gr.	Com. num.	Sym.
1. Potassium,	0·865	39·20	K.
2. Sodium,	0·972	22·98	Na.
3. Ammonium,(?)		18·06	NH_4.
4. Lithium,		6·43	Li.
5. Barium,	4·00	68 67	Ba.
6. Strontium,	2+	43·84	Sr.
7. Calcium,	2+	20·00	Ca.
8. Magnesium,	1·87	12·10	Mg.
9. Aluminium,	2·60	13·68	Al.
10. Glucinum,		6·97	Gl.
11. Zirconium,		33 60	Zr.
12. Thorium,		59·51	Th
13. Yttrium,		33·20	Yt.
14. Erbium,			Er.
15. Terbium,			Tr.
16. Cerium,		47·26	Ce.
17. Lanthanium,		47·04	La.
18. Didymium,		49 60	Di.
19. Manganese,	7·05	27·57	Mn.
20. Iron,	7·80	28·00	Fe.
21. Chromium,	5·90	26 24	Cr.
22. Cobalt,	8·60	29·52	Co.
23. Nickel,	8·279	29·57	Ni.
24. Zinc,	6·86	32·53	Zn.
25. Cadmium,	8·604	55·74	Cd.
26. Tin,	7·285	58·82	Sn.
27. Titanium,	5·28	25·17	Ti.
28. Lead,	11·445	103·56	Pb.
29. Bismuth,	9·80	106·40	Bi.
30. Antimony,	6·702	64 52	Sb.
31. Uranium,		60·00	U.
32. Tungsten,	17·60	92·00	W.
33. Molybdenum,	8·615	47·12	Mo.
34. Vanadium,		68·46	V.
35. Copper,	8·895	31·65	Cu.
36. Mercury,	13·596	100·00	Hg.
37. Silver,	10·474	108·00	Ag.
38. Gold,	19·258	98·22	Au.
39. Platinum,	21 about	98·56	Pt.
40. Osmium,	10 about	99·53	Os.
41. Iridium,	15·683	98·66	Ir.
42. Palladium,	11·30	53·22	Pd.
43. Rhodium,	10·64	52·17	Rh.
44. Ruthenium,	8·60	51·68	Ru.
45. Arsenic,	5·75	75·00	As.
46. Silicium, (?)			
47. Niobium,			
48. Pelopium,			
49. Tellurium,	6·20	64·25	Te.
50. Tantalium,		184·90	Ta.

328. What is the heaviest metal in this table? What is the lightest? Write the sp. gr., com. num., and sym. of those metals which have been described in this work.

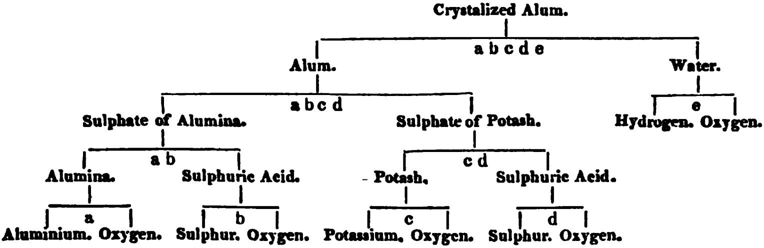
PART III.

ORGANIC CHEMISTRY.

329. This branch of chemistry has all the interest and novelty of another science. An agent hitherto not considered, *the principle of life*, controls or modifies to such a degree the laws, properties, and forms of matter, that the latter is the mere instrument of life, or the material out of which life produces its grand results. Among the effects of this new agent, are the following :

1. The products of life are remarkable for *the great variety of compounds which a few elements produce.* Carbon, hydrogen, oxygen, and nitrogen, are both the foundation and the superstructure of this department of chemistry. With these are occasionally associated phosphorus and sulphur. From these few elements, changes and compounds without number are produced by the principle of life.

2. Organic substances are also remarkable *for the complexity of their structure.* The bodies hitherto described in inorganic chemistry, have been invariably made up of elements or *pairs* of elements. This system, called the *binary* system*, may be illustrated by the following example :



Five *pairs*, *a*, *b*, *c*, *d*, and *e*, make up the compound *abcde* or crystalized alum. These pairs also unite with each other in

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*Latin *bis*, twice.

329. What is said of organic chemistry ? What new principle is here found ? What are the effects of this principle on matter ? For what are the products of life remarkable ? What four substances compose, for the most part, organic bodies ? What other bodies are sometimes associated with these ? In what other respect are organic substances remarkable ? Explain the diagram. What

such a manner as to preserve through every grade of combination the relation of *two bodies*, or a pair of bodies. Thus *a* and *b* unite in *ab*, *c* and *d* in *cd*; *ab* and *cd* unite in *abcd*, and *abcd* with the single pair *e* in *abcde*, or crystalized alum.

The plan on which organic substances are formed is strikingly different. The combination is not usually by pairs, but in compounds of *three* or *four* elements. These triple or quadruple compounds enter into combinations, and pass through decompositions, and through all the changes of the bodies to which they belong as *one*, or as simple bodies, and are, therefore, called *compound radicals*.

3. *Organic bodies contain within themselves causes for their own decomposition.* The constituents of inorganic bodies are usually united by their most powerful affinities, and, therefore, these bodies have considerable permanence. But the vital principle unites in organic bodies several elements into a compound, for which they have weak affinities, while for each other their affinities are powerful. Thus carbon, oxygen, hydrogen, and nitrogen, are united in organic bodies in one compound, but the separate affinities of oxygen for carbon (to form carbonic acid), oxygen for hydrogen (to form water), nitrogen and hydrogen (to form ammonia), are more powerful than those which these bodies possess for the general compound, or for the organic body. While these opposing forces remain exactly balanced, the compound is preserved, but the moment one of them, from some accidental cause, acquires a preponderance over the rest, the equilibrium is destroyed, and the compound breaks up into two or more bodies of simpler and more permanent constitution. Heat produces this result by exalting the attraction of oxygen for hydrogen and carbon; hence almost all organic bodies are destroyed by a high temperature. Mere molecular disturbance will sometimes cause destruction when the instability is very great.

4. *Organic forms are produced by the development of multitudes of little cells, or membranous bladders, containing a fluid, while inorganic forms are produced by the laws of crystalization.* The membrane which constitutes the cell-wall is freely permeable by fluids, and, consequently, by the gaseous matter contained in those fluids. Food is thus carried to the interior of the mass for the nourishment of fresh cellules,

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is the usual method of combination, by which organic bodies are formed? What is meant by a compound radical? What is the third peculiarity of organic bodies mentioned? How is this explained? How are organic bodies generally each produced from a *living point* or germ within the substance of the pre-existing cells.

The living cell exerts a wonderful influence over chemical action. It secretes and prepares its own food, and, in one case, decomposes carbonic acid, rejecting the oxygen and uniting the carbon to the elements of water; in another case (i. e.—a cell of a different kind), it produces out of the constituents of air the odors of flowers; in a third case, it converts the albumen of the blood into milk. Though performing these various functions, the cell always appears to the eye the same.

Crystaline bodies are, however, found in plants as well as in inorganic substances, produced by the spontaneous crystalization of saline substances. This subject has been recently investigated by Prof. Bailey, who discovered that every species of oak, birch, chestnut, poplar, elm, locust, and all the common fruit trees, were filled with crystals, crowded together in vast numbers. The size of these crystals was very small, being seen only by a powerful microscope, and measuring in some cases not more than the $\frac{1}{1250}$ of an inch in length, but their number was so great, that within the compass of a square inch of bark, not thicker than a sheet of writing paper, more than a million were collected together. Sometimes the arrangement of these crystals appeared like an elegant piece of mosaic work, as represented in Fig. 95, which is a section of the bark of a species of poplar. The existence of these crystals was first discovered by examining the ashes of the oak, and they were afterwards found in the ashes of many other trees. The delicate crystaline structure found in the ashes of the maple leaf, is represented in Fig. 96. Most of the forest trees, not only in our own country, but in all parts of the world, are full of these crystals, so that they may be obtained for examination by merely scraping the wood in-

Fig. 95.

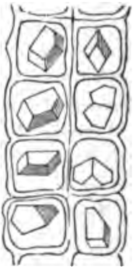
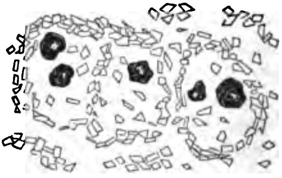


Fig. 96.



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developed? Are crystaline bodies found within plants? Explain Figs. 95 and 96. What is said of the occurrence of isomeric bodies in organic chemistry? What method of investigation may be employed in organic chemistry? How is organic chemistry divided? How is vegetable chemistry divided?

to a watch-glass filled with water, and picking out the woody particles, or by preparing the ashes of the wood with Canada balsam on a slip of glass.

5. *Isomeric bodies, or bodies differing in properties but identical in composition, are of constant occurrence in organic chemistry.*

6. In the study of inorganic bodies, *both analysis and synthesis* are employed; but in organic chemistry, *analysis alone* can be usually employed. Could we obtain the power of uniting life to matter, we might then build up its compounds and imitate its results. But as power to add life to dead matter is and must ever be beyond our reach, we can destroy but cannot reproduce any of the forms of living matter. By breaking down the fabric we can learn the materials of which it is composed, but we cannot rear again the edifice.

These are some of the effects of the agency of life on matter, which it is the object of organic chemistry to examine. As life is divided into animal and vegetable, so this subject includes animal and vegetable chemistry.

Animal chemistry will be reserved for the close; vegetable chemistry will at present occupy our attention, and will be considered under two sections, the *non-azotized substances*, or those substances which contain no nitrogen, and the *azotized*, or those bodies of which nitrogen is an element.

VEGETABLE CHEMISTRY.

SECTION 1.—NON-AZOTIZED BODIES.

SECT. I.—1. THE STARCH GROUP.

330. Three of the four elements of the organic kingdom are contained in this group; carbon, hydrogen, and oxygen, of which hydrogen and oxygen are always in equal proportions, or in the proportions to form water.

Starch (dextrine),	$C_{12}H_{10}O_{10}$.
Cane sugar (crystalized),	$C_{12}H_{11}O_{11}$.
Grape sugar,	$C_{12}H_{14}O_{14}$.
Milk sugar,	$C_{12}H_{12}O_{12}$.
Gum,	$C_{12}H_{11}O_{11}$.
Cellulose,	$C_{12}H_{10}O_{10}$.

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330. What elements enter into the constitution of the bodies of the starch

Starch, or *fecula*, is a body of great interest in many respects, from its universal occurrence in the vegetable kingdom, the important offices it there fulfills, and the various changes it may be made to undergo. There is scarcely a plant or a part of a plant which does not yield more or less of this substance. Frequently the quantity is so great that it produces in the plant an enormous distention of the cellular tissue. Thus the potato is swollen out of all shape or regular figure by an accumulation of starch mingled with water within the cells. Starch constitutes a very important and often a very abundant ingredient in seeds of all kinds. The interior of the stems of many palms is often filled with loose cellular substance rich in starch.

If a fresh plant is bruised and macerated in water, and the liquid then squeezed out through a linen cloth, a large portion of the starch will pass with the juice from the vegetable tissue, and will settle after standing as a mealy mass. Potatoes, grain, and many orchidaceous plants, are very rich in starch. Starch is a white, pulverulent, opaque powder, which under a powerful microscope is found to consist of small, generally regular, grains or globules. Their appearance within the cells of the plant is shown in Fig. 97, which represents a section of some of the cells of the potato. The starch granules from different plants vary both in magnitude and form. Several of these forms are exhibited in the accompanying figures. Fig. 98, represents potato starch. These granules glisten in the sun; they are hard to the touch, and are always of a pulverulent rather than a concrete character. They are egg-shaped grains, with scales overlapping each other, and on one side each granule exhibits 2 dark lines, as at *a*. The granules of wheat (Fig. 99.) are much smaller than those of potato starch. They are also much harder. The granules of peas (Fig. 100.) are also much smaller than those

Fig. 97.

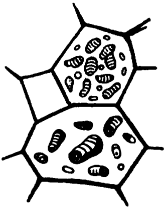


Fig 98.

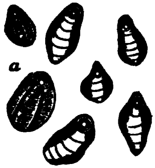


Fig. 99.

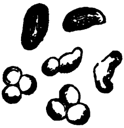
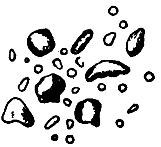


Fig. 100.



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group? In what proportions are the hydrogen and oxygen of these bodies? Write the bodies of this group and their constitution. What is said of starch?

of the potato. *Arrowroot* is a starchy meal, prepared in the East and West Indies, from the roots of some marsh plants. Its granules are intermediate in size between those of wheat and those of the potato. They are transparent when examined by the microscope, and, therefore, they form a powder of less brilliant whiteness than that of wheat.

Sago is prepared by gently heating starch with constant agitation, till it dries up into hard, horny, granules. The genuine sago comes from India, where the starch for its preparation is extracted from the pith of many of the palm trees. *Tapioca* is prepared from the root of a South American plant, which is now also cultivated for this purpose in the West Indies. This root contains a poisonous juice from which it is purified by pressure and heat.

When starch is put into cold water, and the water gently heated, its properties are completely altered. At a temperature a little below the boiling point the granules burst, and their contents form with the water a nearly transparent, gelatinous mass. This is freely miscible with water, if not in fact dissolved in that liquid. Minute shreds of membranous matter are discovered floating in the liquid, which are the envelops of each granule of starch. These give to the solution a slightly opalescent appearance. The swelling of many of our most common articles of food, such as rice, barley, beans, peas, &c., when boiled with water, is owing to the large amount of starch which they contain.

Starch is insoluble in cold water and in alcohol, and is precipitated by many of the metallic oxides, as lime, baryta, and oxide of lead, and also by a large addition of alcohol. Infusion of galls throws down a copious yellow precipitate containing tannic acid (353.), which redissolves when the solution is heated. By far the most characteristic reaction, however, is that with free iodine, which forms with starch a deep indigo-blue compound (iodide of starch), which dissolves in pure water, although it is insoluble in free acid or saline matter. The blue liquid loses its color by heat, and this loss is permanent if the boiling is long continued. In this case the iodine is volatilized, and the blue compound therefore decomposed. If, however, the heat be quickly withdrawn, before the temperature reaches 212°, the color returns, as the iodine is, in this case, not entirely volatilized.

Explain Figs. 97, 98, 99, and 100. What is the action of hot water on starch? Mention some of the properties of starch;—the principal test.

When put in a dry state into iodine, starch acquires a purplish black color.

331. *Dextrine and grape sugar.* Thick gelatinous starch, when boiled for a few minutes with dilute acid, changes to a fluid as limpid as water. If the acid is neutralized with carbonate of lime, and the liquid gently evaporated to dryness, a substance is obtained having the appearance and many of the characters of gum. This substance is called *dextrine*, or gummy starch. *In chemical composition it is precisely the same as starch.* If, instead of interrupting the ebullition as soon as the mixture of acid and starch has become clear, we continue it for several hours, adding from time to time small quantities of water to supply the place of that lost by evaporation, and then separate the acid, and boil down the solution to a small bulk, we obtain a sirupy liquid, very sweet to the taste, which on standing for a few days, entirely solidifies to a mass of *grape sugar*. This product exceeds in weight the starch from which it was obtained.

In the transformation of starch to dextrine, no change of composition is produced, and none also in the change of dextrine to grape sugar, except the absorption of the elements of water. The acid employed is withdrawn at the end of the experiment in its original amount, and nothing is absorbed from the air. Starch is also converted into sugar, by the action of a peculiar ferment, called *diastase*, which is contained in an infusion of malt. Diastase is also found in germinating seeds and buds while developing. It dissolves and converts to food the starch which is stored up for the nourishment of the young plant. By diastase, gelatinous starch may be converted in a few minutes, at a temperature of 160°, into dextrine, and soon after into grape sugar.

In germination, potatoes becomes soft, mucilaginous, and afterwards sweet; the dextrine formed from the starch renders them mucilaginous, and the sugar formed from the dextrine renders them sweet. The quantity of starch in potatoes is found to vary in different months. In August 100 pounds of potatoes contained 10 pounds of starch; in September 14 pounds; in October 15; in November 16; in December 17; in January 17; in February 16; in March 15; in April 13; in May 10. The starch, therefore, in-

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331. How may dextrine be formed? What is the composition of dextrine? How may grape sugar be formed? What is diastase? What is its action upon starch? Why do potatoes in germination become mucilaginous and afterwards sweet? What is said of the quantity of starch contained in potatoes in the different months of the year? When do apples and pears contain starch?

creases during the winter, and in the spring, after the germinating principle is excited, it diminishes. Unripe apples and pears contain starch, as is shown by the test with iodine. When completely ripe they cease to give this reaction, the starch having become converted into dextrine and sugar, which gives a sweet taste to the fruit. Frost produces a similar effect on those vegetables which are rich in starch; hence frozen potatoes, apples, &c., have a sweet taste after being thawed.

Grape sugar is abundantly diffused throughout the vegetable kingdom. It may be extracted in large quantity from the juice of sweet grapes, and also from honey, of which it forms the solid crystaline portion, by washing with cold alcohol, which dissolves the fluid sirup. It is found in many vegetables, and is especially abundant in fruits, as plums, pears, figs, grapes, &c. The white coating of plums, and the white, sweet grains in raisins, consist of it. Compared with cane sugar it is much less soluble in water. One ounce of cold water will dissolve three ounces of cane sugar, but only two-thirds of an ounce of grape sugar. It is also much less sweet. Two and a half ounces of grape sugar are equivalent to only one ounce of common sugar in this respect. The crystals of cane sugar are bold and distinct; grape sugar separates from its solutions in granular warty masses presenting crystaline faces but rarely. When pure it is nearly white. When heated it melts and loses 4 eq. of water, and, at a higher temperature, blackens and suffers decomposition. Alkalies, which turn grape sugar brown, produce little effect on cane sugar, and sulphuric acid dissolves grape sugar without blackening, but turns common sugar black. By these two tests, therefore, grape and cane sugar may be distinguished. Another test is to add caustic potash to the sugar mixed with a solution of copper. When this mixture is heated, grape sugar throws down a green precipitate, which turns deep red, while the solution is left colorless. The action with cane sugar is very different. The mixture in this case alters very slowly, gradually forming a red precipitate, and leaving the solution blue. Grape sugar, like cane sugar, gives with common salt a soluble compound of sweetish saline taste, which crystalizes in a regular and beautiful manner.

332. *Cane sugar* is found abundantly in the juices of many plants, but is chiefly extracted from the sugar cane. By

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What becomes of this starch when the fruit ripens? What is said of grape sugar? In what respects does it differ from cane sugar? By what tests may these two kinds of sugar be distinguished?

evaporating the cane liquor, it is crystalized in large rhombic prisms, which are colorless. Sugar is permanent in the air, phosphorescent by friction and electricity, and of the sp. gr. 1·6. It has a pure sweet taste, and is very soluble in water, uniting with a third of its weight of cold water, and dissolving to an almost unlimited extent in hot water. It is dissolved by alcohol, but not as readily, and in absolute alcohol it is almost insoluble. When heated, it melts and gives rise to a yellowish, transparent body, called *barley sugar.* If kept at a temperature of 630° it turns to a reddish-brown substance called *caramel.* Sugar has the property of combining like an acid with some bases, as potash, lime, ammonia, oxide of lead, &c. These compounds are called *saccharates.*

Sugar is a powerful antiseptic, and is now used to a considerable extent for preserving meat and fish, for which purpose it possesses the advantage of acting in a much less quantity than is requisite of common salt, and of not destroying the taste nor impairing the nutritive qualities of the food.

In many parts of the continent of Europe, sugar is manufactured on a large scale from the *beet root,* which contains about 8 per cent. of that substance. Large quantities are also obtained from the sap of the maple tree.

333. *Milk sugar, lactine,* is obtained in large quantities by evaporating whey to a sirupy state, and purifying by animal charcoal the lactine which slowly crystalizes out. It is much less sweet than either cane or grape sugar. It is also harder and less soluble, requiring 5 or 6 times its weight of cold, and 2½ times its weight of hot water to dissolve it. When mixed with hydrochloric or sulphuric acids, it becomes converted into grape sugar, and this change is hastened by boiling. It forms four-sided prisms which are white, translucent, and of great hardness. When heated it loses water, and at a high temperature blackens and decomposes. A peculiar acid, called *lactic acid,* is formed from milk sugar when allowed to stand, and this acid coagulates the milk, and causes it to turn sour.

334. The *sweet principles of plants* appear to be rather numerous. Already five or six distinct bodies of this kind have been pointed out and examined, and it is probable that

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332. In what plants is cane sugar found? Mention some of its properties. How is it converted into barley sugar?—caramel? What is said of the action of sugar with the bases? What are its compounds called? What is said of the antiseptic properties of sugar?

333. How is milk sugar obtained? Mention some of its properties. What body is formed when milk is allowed to stand? What effects does lactic acid produce on milk?

others exist which are yet undescribed. Thus, besides the sugar of cane, beet root, &c., a second variety constitutes the sweet matter of all ordinary fruits; a third is found in certain fungi; a fourth in common liquorice; a fifth exists in manna, which is an exudation from a species of ash in Southern Europe; a sixth is found in milk.

335. *Gum—Gum Arabic.* Gums of various kinds exist in many plants, and often in such abundance that they exude from the bark as a viscid liquid, and harden upon it in transparent globular masses. Examples of this kind are found in beach and cherry trees. Gum Arabic comes from an African tree, a species of acacia, from which it exudes spontaneously. It is the best type of this class of bodies. It forms white or slightly yellowish irregular masses, which are destitute of crystaline structure, and break with a smooth conchoidal fracture. It is bleached by exposure to the sun, and its powder is nearly or quite white. It is soluble in water, forming a viscid, adhesive, tasteless solution, from which pure *arabine*, or the soluble gummy principle, may be precipitated by alcohol. It has a very feeble, slightly sweetish taste, and, when pure, dissolves wholly in the mouth. It undergoes no change by time when kept in a dry place. Its aqueous solution, if strong, remains for a considerable time unaltered, but at length becomes sour, in consequence of the production of acetic acid (346.) At a temperature between 300° and 400°, it becomes soft, and may be drawn into threads.

Gum Arabic is used instead of paste or glue for joining together paper, &c., and for uniting in a mass certain pulverulent substances, as crayons, pastiles, &c. It is employed also in calico printing as a thickening material for colors and mordants, and in finishing and dressing operations. Gum or arabine ($C_{12}H_{11}O_{11}$.) is isomeric with crystalized cane sugar.

336. *Pectine.* This substance exists more or less in all vegetables, especially in those fruits and roots from which jellies are prepared. To the juices of these fruits, especially when boiled with sugar, it gives the property of hardening into a gelatinous mass on cooling. From vegetable juices

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334 How many sweet principles have been discovered in plants? Mention some of these.

335. Whence is gum Arabic obtained? Mention some of its properties;—its uses;—its composition.

336. What is said of pectine? How is pectine converted into pectic acid? What are some of the properties of this acid?

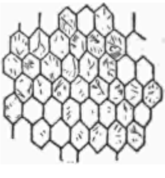
it may be precipitated by alcohol. As thus obtained, it forms when moist a transparent jelly, imperfectly soluble in water, and tasteless, which dries up to a translucent mass. It is very nearly allied to the gums.

A striking peculiarity of this substance is, that by the agency of a fixed alkali or alkaline earthy base, it is instantly converted into *pectic acid*, which unites with the base to form a *pectate*. On the addition of an acid to this pectate, it is decomposed and the pectic acid liberated. This acid is in the form of a colorless jelly, slightly acid, scarcely soluble in cold water, more soluble in hot water. With the latter it forms a solution which is coagulated by the addition of alcohol, lime-water, acids, or salts, or even sugar, if allowed to stand for some time.

337. *Cellulose, vegetable tissue, lignine*, is that portion of every plant which remains behind after the action of several solvents, such as water, dilute acid and alkali, alcohol and ether, have been successively applied. By these solvents the gum, sugar, resin, coloring-matter, &c., are removed, and there is left behind a white fibrous skeleton which is cellulose. This is the fundamental material of the structure of plants. It is employed in the organization of cells and vessels of all kinds. What bone, flesh, and skin, are to the animal, cellulose is to the plant.

In Fig. 101, is represented a transverse section of the sugar cane as seen by the microscope. This is so thin as to display only one layer of cells, but a thicker section would show a second set of the same kind of cells behind the first. The forms of vegetable cells are exceedingly various, being globular in some plants, angular in others, and of the latter some are three sided, others square, but the greater part are hexagonal or six-sided figures.

Fig. 101.



In the young leaves, and in the pulp of fruit and roots, as apples, plums, carrots, &c., cellulose is very finely ramified, tender, soft, and easily digestible; in straw, wood, and the husk of grain, it is hard and indigestible; it forms the stones of plums, cherries, and peaches, and the shells of nuts, and also the light pith of the elder, the substance of cork, and the long pliant fibres of hemp, flax, and cotton.

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337. What is cellulose? What are some of the different forms under which it occurs? Where is cellulose seen in a state of purity? Mention

Under a good microscope the ultimate fibres of cellulose present the appearance of minute ribands with rolled or thickened edges.

Cellulose is seen in a state of purity in the fibres of linen and cotton. It is of perfect whiteness, insoluble in water and alcohol, and tasteless. Strong and cold sulphuric acid converts it into dextrine. When digested in fused potash, dissolved in its weight of water, linen yarn becomes immediately yellow, while cotton remains white, and in this way these two forms of cellulose may be distinguished. They may also be distinguished by the appearance of their fibres under the microscope. The fibres of cotton are flat, riband-like, and more or less contorted or shrivelled ; those of linen are straight, round, and with cross knots at certain distances.

338. *Wood* consists chiefly of cellulose. Dry timber consists on an average of 96 parts of fibrous and 4 of soluble matter in 100, but these proportions vary somewhat with the season, the soil, and the plant. Wood becomes snow-white when exposed to the action of chlorine. If too long exposed, the chlorine destroys the vegetable tissue by abstracting the hydrogen. When dipped in strong sulphuric acid, wood is charred, because the acid attracts from it hydrogen and oxygen and leaves carbon. The oxygen and hydrogen unite to form water by the presence of sulphuric acid (disposing affinity, p. 64), and the water thus formed unites with the sulphuric acid. When digested with dilute sulphuric acid, it is transformed first into gum, and afterwards, by ebullition with water, into grape sugar. By nitric acid wood is dyed yellow, being oxidized by this acid. By long continued treatment, all the carbon may be oxidized into carbonic acid, and all the hydrogen into water.

339. *Gun-cotton, pyroxiline,* is explosive vegetable tissue, prepared by oxidizing cotton with nitric acid. Half an ounce of the strongest nitric acid (sp. gr. 1·5) is mixed with an ounce of strong sulphuric acid. The object of the latter is to attract and retain the water contained in the nitric acid, and that which separates from the cotton. This mixture is poured into a porcelain mortar or bowl, and as much cotton

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some of its properties. How may the cellulose of linen and cotton be distinguished?

338. Of what is wood chiefly composed? What is the action of chlorine upon wood?—strong sulphuric acid? Into what is wood converted when digested with dilute sulphuric acid? What is the action of nitric acid on wood?

339. What is gun-cotton? How is it prepared? Mention some of its prop-

pressed in with the pestle as can be moistened with the acid. Loose cotton is not essential, as cotton cloth, wick yarn, printing paper, &c., will answer. When the cotton has soaked for five minutes, it is taken out with a glass rod, put into a vessel of water, and washed repeatedly with fresh portions of water until it no longer reddens blue test-paper. The cotton is then squeezed out with the hand, spread upon a sheet of paper, and dried in an airy place. It is dangerous to dry it on a stove, as it easily takes fire. One hundred parts of pure lignine yield 176 of pyroxiline. It is white, inodorous, insoluble in water, soluble in ether and caustic potash. When touched with a red hot iron it explodes, and leaves no residue. By a stroke of a hammer the part struck explodes and drives off the remainder unconsumed. Its power in propelling balls is about eight times greater than that of gunpowder. This great energy depends upon the fact that it is completely resolved by its combustion into aqueous vapor and permanent gases, which are carbonic acid, carbonic oxide, and nitrogen. Its purity (i. e. the conversion of the lignine of which it is made into pyroxiline) may be ascertained by sulphuric acid of the density 1·4 to 1·76, which dissolves it if pure without becoming colored, but if lignine is present the acid is soon colored.

SECT. I.—2. ORGANIC ACIDS.

340. Sulphuric, nitric, and other inorganic or *mineral* acids are formed artificially, but the acids which are now to be described are the product of the vital principle alone. By decomposing these acids we arrive at their constitution, but we cannot again unite their elements to form these bodies. The following table includes the most important of these acids:

Oxalic acid,	$C_2O_3, HO+$	$2HO$.
Tartaric acid,	$C_8H_4O_{10},$	$2HO$.
Acetic acid,	$C_4H_3O_3,$	HO.
Citric acid,	$C_{12}H_5O_{11},$	$3HO$.
Malic acid,	$C_8H_4O_8,$	$2HO$.
Tannic acid,	$C_{18}H_5O_9,$	$3HO$.
Gallic acid,	$C_7HO_3,$	$2HO$.

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erties. To what is the great energy of its explosion owing? How may its purity be determined?

340. How are the organic acids produced?

341. *Oxalic acid* is formed by the action of nitric acid on starch, sugar, and many other substances. It is the highest state of vegetable oxidation, for if more oxygen be added it loses its vegetable nature, and is resolved into carbonic acid and water. In its formation, this excess of oxygen which it contains compared with any other organic compound, is furnished by nitric acid. It may also be obtained from organic substances by the action of caustic potash. Thus if wood shavings be mixed with a solution of caustic potash, and exposed to a heat considerably higher than 212°, they will be partially decomposed, and converted into oxalic acid, which then combines with the alkali forming oxalate of potash. This is perhaps the cheapest method of obtaining oxalic acid.

Oxalic acid is a colorless crystalized solid, possessing considerable volatility, and a strong sour taste. Its crystals have the shape of slender, flattened, four or six-sided prisms, They dissolve in about nine times their weight of cold, and in their own weight of boiling water. They are also soluble in alcohol. Oxalic acid is very poisonous. Instances are on record of its proving fatal in ten minutes, and few survive the effects of a poisonous dose beyond an hour. Magnesia and chalk are the proper antidotes.

According to the formula $C_2O_3, HO+2HO$, crystals of oxalic acid contain 1 eq. of basic water (water of constitution), with two eq. of water of crystalization. The latter may be removed by exposure to a low heat, and the acid then becomes a white powder and sublimes without difficulty. The symbol of the acid in this state will be C_2O_3, HO (omitting 2HO from the above formula). Any attempt to simplify its constitution still farther by driving off the basic water HO, in order to isolate the acid as C_2O_3, is attended by its decomposition, as follows:

C_2O_3+HO=oxalic acid with basic water.

This may be divided into

HO=water.

(escapes in watery vapor)

CO_2=CARBONIC ACID.

(first product of the decomposition of oxalic acid.)

CO=CARBONIC OXIDE.

(second product of the decomposition of oxalic acid.)

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341. How is oxalic acid formed? What is said of the amount of oxygen which it contains? Mention some of the properties of oxalic acid? Write and explain its formula. What portion of the water contained in crystals of oxalic acid may be expelled by heat? What will the formula then become? Explain the diagram. What is said of the relations of oxalic to the other acids?

All the other organic acids can be converted into oxalic by the addition of oxygen, but oxalic acid cannot be made by any chemical process to return to a lower state of oxidation.

Oxalic acid occurs naturally in several plants, in union with potash or lime. It has a very strong affinity for lime, and forms with it an insoluble precipitate of oxalate of lime, whenever the acid and the earth are brought into contact. Hence oxalic acid, and its soluble combinations, are the best tests for lime which we possess; and lime, on the other hand, is the best test for oxalic acid. So strong is the mutual attraction between this acid and lime, that the former takes the latter even from sulphuric acid. Hence the addition of a soluble oxalate produces a white cloud in a solution of sulphate of lime. Oxalic acid is used in calico printing, and in removing ink spots from linen or paper. This it does by dissolving the oxide (sesquioxide) of iron, and both are removed by washing. Calico is dyed yellow by dipping it in a solution of protosulphate of iron (green vitriol.) Ammonia is then added, which withdraws the sulphuric acid and leaves the iron as protoxide. This, on exposure to the air and drying, becomes converted into the yellow sesquioxide. On this ground white patterns are stamped with oxalic acid, which dissolves the sesquioxide wherever it touches, and leaves a white figure.

342. *Tartaric acid* is the acid of grapes, of tamarinds, of the pine-apple, and several other fruits, in which it occurs as bitartrate of potash. Tartrate of lime is also occasionally met with. Tartaric acid is a white crystalized solid, in the form of irregular six-sided prisms. It is unalterable in the air and possesses a strong acid taste which becomes agreeable when the acid is sufficiently diluted with water. It is soluble in five or six times its weight of cold, and twice its weight of boiling water. It is also soluble in alcohol. The solution reddens litmus strongly. A weak aqueous solution is decomposed by keeping, becoming covered with a mouldy pellicle.

343. *Acid tartrate of potash, cream of tartar*, KO, HO, $C_8H_4O_{10}$. During the fermentation of grape juice a crystaline, stony matter is deposited. This consists chiefly of acid tartrate of potash, with a little tartrate of lime and col-

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How does oxalic acid occur naturally? What is the best test for oxalic acid? Mention some of the uses of this acid?

342. Write and explain the formula for tartaric acid. Where is this acid found? Mention some of its properties.

oring matter, and is the source of all the tartaric acid of commerce. It is purified by solution in hot water, and the coloring matter is removed by animal charcoal. It forms small, transparent or translucent, prismatic crystals, irregularly grouped together, which are hard and gritty between the teeth, and dissolve slowly in the mouth. It is permanent in the air, and soluble in 15 parts of boiling water, but the greater part separates on cooling, leaving about $\frac{1}{184}$ or less dissolved in the cold liquid. Its solubility in water is greatly increased by the addition of borax. It is insoluble in alcohol. It has an acid reaction and a sour taste.

344. *Tartrate of potash, soluble tartar*, $2KO, C_8H_4O_{10}$, may be made by adding carbonate of potash to cream of tartar. It is very soluble, and crystalizes with difficulty in irregular six-sided prisms, which are permanent in the air, and have a bitter, saline taste.

345. *Tartrate of antimony and potash, tartar emetic*, $KO, Sb_2O_3, C_8H_4O_{10}+2HO$, is made by boiling oxide of antimony in solution of cream of tartar. It is deposited from a hot and concentrated solution in crystals derived from an octahedron with a rhombic base, which dissolve in 15 parts of cold and 3 of boiling water. The solution is decomposed by both acids and alkalies. Sulphuretted hydrogen separates all the antimony as a sulphuret. Crystals of tartar emetic are colorless, and have an acid and extremely disagreeable taste. When exposed to the air they effloresce and become opaque.

346. *Acetic acid, pyroligneous acid, vinegar.* When alcohol is oxidized it is converted into vinegar. This does not take place by mere exposure to the air, or even to oxygen gas, as pure alcohol is not affected by either of these. To produce this effect it is necessary to add a *ferment*, as yeast, vinegar, &c., which, by disposing affinity (p. 64.), generates an action that would not exist without its presence. A tub, *a*, (Fig. 101,) 12 or 15 feet high, is filled with shavings of beach-wood and is furnished with a perforated shelf, *b*, near the top. . Through this shelf small holes are made, and strings let down with knots tied in the upper extremities, which prevent them from falling through. The alcohol is

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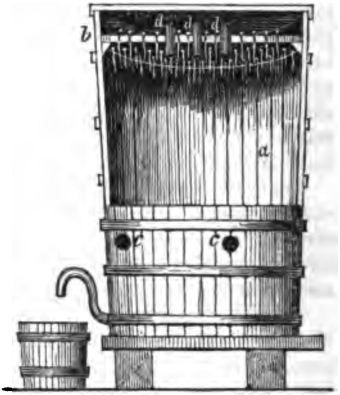
343. Write and explain the formula for cream of tartar? How is this substance produced? Mention some of its properties.

344. Write and explain the formula for tartrate of potash. How does this formula differ from the last? How is tartrate of potash produced?

345. Write and explain the formula for tartar emetic. How is tartar emetic made? Mention some of its properties.

poured into the tub above the shelf *b*, and trickles down slowly over the threads, and thus diffuses itself over the shavings, forming a very thin layer, which presents to the air *a surface* many thousand times more extensive than was produced by any former method. Several large holes *c, c,* are bored around the lower part of the tub, and also in the perforated shelf at *d, d, d,* to produce a free circulation of air. The large holes *d, d, d,* are filled with tubes which rise above the alcohol upon the perforated shelf. The process of fermentation within the tub produces an elevated temperature (104°). The heated air, therefore, rises and passes off through the tubes *d, d, d,* while fresh air enters at *c, c,* and thus a circulation is kept up within the tub. The air passing through the shavings within, gives up its oxygen to the alcohol, and converts it into vinegar. The *ferment* used in this process is strong vinegar, with which the tub and the shavings are previously moistened. Brandy, beer, wine, &c., may be converted into vinegar in a few hours by being passed through the tub three or four times.

Fig. 101.



In the United States, vinegar is usually made from cider, which, by long exposure to the atmosphere, attracts additional portions of oxygen, and is converted into acetic acid. The yellow or brownish color is often imparted to it by burnt sugar, or extract of chicory.

Dilute acetic acid, or distilled vinegar, used in medicine, should always be examined for lead or copper, as it sometimes contains these impurities, derived from the metallic vessel or condenser used in the process. The strength of any sample of acetic acid cannot be safely inferred from its density, but is easily determined by the quantity of dry carbonate of soda necessary to saturate a known weight of the liquid. The water contained in vinegar freezes on exposure to cold sooner than the acid; hence, in this way, weak vine-

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346. Write and explain the formula for acetic acid. How is acetic acid formed? Explain Fig. 101. Mention some of the properties of acetic acid.

gar may be strengthened. The same action is observed when wine is exposed to the cold.

Acetic acid unites in all proportions with water, and dissolves to a certain extent in alcohol. It is a solvent of a great number of substances, such as the volatile oils, camphor, gluten, resins and gum-resins, fibrine, albumen, &c. It is one of the few vegetable acids that volatilize without decomposition. Its boiling point is somewhat higher than that of water, and when boiled in open vessels it takes fire, and burns with a blue flame like alcohol. It attracts humidity from the atmosphere, and should, therefore, be preserved in well stopped bottles.

347. *Acetate of lead*, $PbO, C_4H_3O_3+3HO$, is prepared on a large scale by dissolving litharge in acetic acid. It may be obtained in colorless, transparent, brilliant needles, which are prisms with dihedral summits. It is usually obtained in commerce as a confusedly crystaline mass, somewhat resembling loaf-sugar. From this fact and from its sweet taste it is called *sugar of lead*. The crystals are soluble in about $\frac{1}{14}$ part of cold water, effloresce in dry air, and melt when gently heated. The water of crystalization is easily driven off by heat, and the salt in the anhydrous state obtained. In this state it suffers the igneous fusion, and afterwards decomposes at a higher temperature. Acetate of lead is soluble in alcohol. The watery solution has an intensely sweet and astringent taste. Spirituous liquors are often sweetened with it, and thus rendered more or less poisonous. It is also used to remove the rancidity of oils. Inferior olive oil is thus made to pass for good.

348. *Subacetate of copper, verdigris*, is made by spreading the marc of grapes upon plates of copper exposed to the air for several weeks, or by spreading on the copper plates pieces of cloth dipped in crude acetic acid. Verdigris is in masses of a pale green color, composed of a multitude of minute, silky crystals. It is a mixture of *several* acetates of copper; one of these may be obtained by digesting in warm water; a second by boiling; the third is found in the insoluble residue. A fine green ink may be prepared by boiling a mixture of 8 parts verdigris, with 1 of cream of tartar, and 8 of water. The solution is then passed through cloth and bottled for use.

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347. Write and explain the formula for acetate of lead. How is this salt prepared? Mention some of its properties. What use is often made of sugar of lead?

348. How is verdigris prepared? What is said of its composition?

349. *Acetate of copper*, $CuO, C_4H_3O_3+HO$, is prepared by dissolving verdigris in hot acetic acid, and leaving the filtered solution to cool. It forms beautiful dark green crystals, which dissolve in 14 parts of cold and 5 of boiling water, and are also soluble in alcohol. This salt is sometimes called *distilled verdigris*, and is used as a pigment. By adding brown sugar to a boiling solution, it is decomposed, and a red crystaline powder subsides.

350. *Acetal*, $C_8H_9O_3$, may be mentioned in connection with acetic acid. It is one of the products of the slow oxidation of alcohol vapor under the influence of platinum (319.) It is a thin, colorless liquid, of pungent, ethereal odor, soluble in 6 or 7 parts of water, and miscible in all proportions with alcohol. It has a peculiar, strongly acid taste, and reduces with great facility certain metallic solutions, such as those of platinum, gold, and silver. Its density is 0·823, and it boils at 203°.

351. *Citric acid* is obtained in large quantities from the juice of limes and lemons. It is found in many other fruits, as in gooseberries, currants, &c., in conjunction with malic acid (352.) From these fruits it is separated by the aid of chalk, which forms with the acid citrate of lime. Sulphuric acid is then added, which takes the base lime, and liberates the citric acid. It is clarified by digestion with animal charcoal, and yields colorless, prismatic crystals, of a pure and agreeable acid taste, and soluble both in hot and cold water. These crystals are of two different forms; those which separate in the cold by spontaneous evaporation contain 5 eq. of water, but those which are deposited from a hot solution contain only 4 eq. Their solution strongly reddens litmus, and, when long kept, is subject to spontaneous change.

352. *Malic acid* is obtained from sour apples, pears, berries of the mountain ash, and many other plants. It may be prepared from the stalks of rhubarb, in which it occurs with oxalate of potash. It is very deliquescent, and, therefore, difficult to crystalize. It is colorless, and soluble in water. Alcohol also dissolves it. The aqueous solution has an agreeable acid taste, becomes mouldy and spoils by keeping.

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349. Write and explain the formula for acetate of copper. State the mode by which it is prepared, and some of its properties.

350. What is said of acetal?

351. Write and explain the formula of citric acid. How is this acid obtained? State some of its properties.

352. Write and explain the formula of malic acid. Where is this acid found? State its properties.

Malic, citric, and tartaric acids, are found associated in almost all acid fruits.

353. *Tannic and gallic acids* are substances in which the acid character is much less marked than in the preceding bodies. They constitute the astringent principles of plants, and are widely diffused throughout the vegetable kingdom. Tannic acid has been divided into several varieties, for, when procured from certain vegetables, it affords a black precipitate with a sesquioxide of iron, but when obtained from other vegetables, it produces a grayish-green precipitate with the same salt of iron. As this acid refuses to crystalize, it has not yet been decided whether these are in fact different varieties, for the color of bodies is so much affected by external causes that it cannot be relied on as a proof of identity or difference.

Tannic acid forms insoluble compounds with starch, gelatine (410.), and other organic bodies, *which thus acquire the property of resisting putrefaction.* When the skins of animals are steeped in an infusion of oak bark or of any other vegetable containing tannic acid, the insoluble compound formed by the gelatine of the skin with the tannic acid constitutes leather. Quick tanning is performed by forcing the liquid containing tannin into the skin by pressure. The formation of leather may also be hastened by using a strong solution of the tanning principle (which may be extracted from the bark), instead of the bark itself. But these quick methods do not produce equally good leather. The common method is to infuse coarsely powdered oak-bark in water, and to keep the skin immersed in this solution a certain length of time. During this process, which is slow and gradual, the skin is found to have increased in weight, and to have acquired considerable tenacity, and impermeability to water. Certain salts are also sometimes used in converting skins to leather. This is most frequently done by laying them in a solution of alum and common salt. The leather prepared in this way is white and more supple than that prepared by the former method.

Tannic acid of the oak may be prepared from nut-galls. A glass vessel *a*, (Fig. 102.) is loosely stopped with cotton or wool at its lower extremity, and half or two-thirds filled with powdered galls. Ether containing, as it invariably does, a little water, is poured upon the powder, and the vessel loosely

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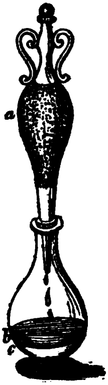
353. Write and explain the formula for tannic and gallic acids. What is said of these acids? In what way is leather prepared? Explain Fig. 102.

Fig. 102.



stopped. The liquid, which after some time collects in the receiver below, consists of two distinct strata, *b* and *c*, of which the lowest, *c*, is a very strong, colorless solution of nearly pure tannic acid in water; the upper, *b*, consists of ether, holding in solution gallic acid, coloring matter, and other impurities. The solution of tannic acid, after being carefully separated, is dried in vacuo with the presence of sulphuric acid. The dry tannic acid thus produced is a slightly yellowish, friable, porous mass, without the slightest tendency to crystalize. It is very soluble in water, less so in alcohol, and very slightly soluble in ether. It reddens litmus, and possesses a pure astringent taste without bitterness.

Artificial tannin has been prepared by adding to 100 grains of charcoal, 500 of nitric acid, diluted with twice its weight of water. This mixture was heated and suffered to digest for two days, when more acid was added, and the digestion continued until the charcoal was dissolved. The solution being evaporated to dryness, left a dark brown mass, which was tannin of a bitter and highly astringent taste.

354. *Gallic acid* is much less abundant than tannic acid, and seems to be produced by an alteration of the latter. A solution of tannic acid when exposed to the air, gradually absorbs oxygen and deposits crystals of gallic acid. The simplest method of preparing this acid in quantity is to make powdered nutgalls into a paste with water, and expose the mixture to the air in a warm situation for two or three months, adding water from time to time to replace that which is lost by drying up. The mouldy, dark colored mass produced, may be strongly pressed in a cloth, and the solid portion boiled in a considerable quantity of water. The filtered solution deposits, on cooling, abundance of gallic acid, which may be drained and pressed, and finally purified by recrystalization. It forms small, feathery, and nearly colorless crystals, which have a beautiful, silky lustre, and require for solution 100 parts of cold, but only 3 of boiling water. The solution has an acid and astringent taste, and is gradually decomposed by keeping. Like tannic acid it yields no precipitate with a protosalt of iron, but forms a deep black precipitate with a persalt, which disappears when the liquid is

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354. How is gallic acid prepared? What are the properties of this acid?

heated, by the reduction of the peroxide of iron to the protoxide. This acid does not, like the last, tan the skin of animals.

SECT. I.—3. THE SACCHARINE FERMENTATION, CONVERSION OF SUGAR INTO ALCOHOL.

355. The conversion of starch into dextrine, and afterwards into sugar, may be illustrated by the following experiment :—Boil two parts of potato starch with twenty parts of water, and add to the paste thus formed one part of gluten (410.) of wheat flour. Expose the mixture for 8 hours to a temperature of from 122° to 167°. It will lose its pasty character, and become by degrees limpid, transparent, and sweet, passing first into dextrine and then into sugar. This production takes place in the germination and kiln-drying of malt. The *mashing* of the brewer, and the sweetening of bread in baking depend upon the same principles. An analogous process takes place in the cooking of certain vegetables, as parsneps, carrots, potatoes, &c., in which sweetness is developed by heat and moisture. The saccharine fermentation of *seeds* in the manufacture of malt, is produced by the following process : Barley is first soaked in water for two or three days. The water is afterwards drained off, and the grain left in this moist state soon heats spontaneonsly, swells, bursts, sweetens, and finally sprouts. When these sprouts are about an inch long, the process is stopped by putting the grain into a kiln, where it is well dried at a gentle heat. It is now *malt*, a crispy and friable substance, which is used in the manufacture of beer.

356. In the manufacture of sugar from the cane, great difficulty arises from the extreme susceptibility of change in the cane juice. The latter, as it runs from the crushing mill is as clear and colorless as water, but decomposition soon commences, which is accelerated by the heat and moisture of the climate, and in a short time the sweet tasted, bland liquid becomes converted into a spirituous or ascescent product, turbid from insoluble, suspended matter, and totally unfit for the purposes to which it was intended to be applied. To guard against this evil, the sugar-boiler always endeavors to conduct the first part at least of the process as rapidly as possible. After the cane-juice is extracted by pressing the

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355. By what experiment may the conversion of starch into dextrine and afterwards into sugar be illustrated? How is the saccharine fermentation of seeds in the manufacture of malt produced?

canes between two cylinders of iron, it is then carefully boiled with lime-water, which neutralizes any free acid, and facilitates also the separation of certain vegetable matters which rise in a thick scum to the surface. This is skimmed off, and the sugar, when thus clarified and sufficiently concentrated, is let off into shallow, wooden coolers, where it concretes. It is then put into barrels with holes in the bottom, through which a quantity of treacle, or molasses, gradually drips, and the sugar, after remaining in these barrels for some weeks, becomes dry and fit for shipment. This is brown or *raw* sugar.

The *refining* of sugar is usually performed in the foreign ports to which it is shipped. For this purpose it is put into a copper pan or boiler, previously charged with a certain quantity of lime-water, with which a portion of bullock's blood has been well mixed by agitation, and also from 5 to 20 per cent. of bone-black (animal charcoal). In this state it is suffered to remain over night. Early in the morning fires are lighted under the pans, and, when the liquid boils, the coagulated albumen (408.) of the blood rises to the surface, and carries the impurities of the sugar with it. Whites of eggs, which also contain albumen, are sometimes used instead of blood. The liquid is kept gently simmering and continually skimmed, until a small quantity taken out in a spoon appears perfectly transparent. This generally takes from 4 to 5 hours. The clear sirup is then boiled down as rapidly as possible, till a small quantity on the thumb is capable of being drawn out into threads by the fore-finger. The more rapidly the boiling is effected without scorching the sugar, the better and *greater* is the product of the sugar. As this object is best accomplished in a vacuum, hence the advantage of the *vacuum process* (28.) The fire is now damped, and the sirup carried off in basins to the coolers. Here it is violently agitated with wooden oars till it appears granulated, for it is upon this agitation that the whiteness and fineness of the grain in the refined sugar principally depend. This breaks down the crystals while forming, and converts the whole into a granular mass. Sugar in this form permits the colored liquid containing molasses, &c., to run off, which would be combined with the solid were it suffered to form in large crystals.

This granular texture also facilitates the next process,

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356. Describe the process by which raw sugar is manufactured ;—by which sugar is refined.

which is to form the sugar into loaves and to purify these loaves. While still warm the sugar is poured into conical moulds, which are inverted, and upon the base thus placed uppermost, clay wet up with water is poured. The water from this clay gradually trickles through the sugar loaves and carries off the coloring matter, which is much more soluble than the crystalized sugar. The loaves thus rendered white are *stove-dried* at a temperature between 95° and 100°. The sirup or drainings collected in pots are mixed with the raw sugar in the next boiling. This sirup is divided according to its fineness, that which drains last from the sugar being, of course, the finest. The first *runnings* are reserved for the coarsest loaves, while the last, being little else than clear sirup, are boiled into loaves of the same fineness as those from which they ran.

Between *sugar candy* and loaf sugar there is the same difference as between calcareous spar and white marble. Large and distinct crystals characterize the former; a confused assemblage of small crystals the latter. Sugar candy is made *without agitation* of the hot sirup. This is poured into pans, across which threads are strung, and to these the crystals attach themselves. The pans are set in a stove, and great care is taken not to disturb the liquid, as upon this depends the largeness and beauty of the crystals. In this state the sugar is left for five or six days, exposed to a heat of about 95°. The crystalized candy is then taken out and washed with lime-water. This takes off the molasses from the *outside*, but a great quantity is enclosed within the crystals.

357. *Conversion of sugar into alcohol.* This is sometimes called the *vinous* fermentation*, as it produces wine and other liquors containing alcohol. As a previous step, the saccharine fermentation must in most cases be formed, so that if sugar is not developed during the life of the plant, it must in this way be produced before the vinous fermentation can take place. Thus barley is converted into malt, and in this state only is it susceptible of undergoing the vinous fermentation by which it is converted into beer.

A solution of sugar in water may be kept for a comparatively long time without undergoing any change, but if blood, albumen, leaven, or any *nitrogenized* matters, in a

* Latin, *vinum*, wine.

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357. What must generally precede the vinous fermentation? Explain the

state of putrescent decay, are mixed with it at a temperature of 70°, the sugar is rapidly decomposed into carbonic acid CO_2, and alcohol $C_4H_6O_2$, as follows:

$C_6H_6O_6$=grape sugar.

Divide this formula into $C_4H_6O_2+C_2O_4$,

$C_4H_6O_2$=ALCOHOL.
(remains in solution.)
C_2O_4=CARBONIC ACID (2 eq. CO_2.)
(passes off as gas.)

The same action takes place in making bread. The leaven causes the sugar which the flour contains to ferment, and, in this case, not only the carbonic acid produced by the fermentation of the sugar, but also the alcohol thus produced, are driven off by the heat of baking. A portion of these gaseous products being entangled within the bread, cause it to puff up, and thus to become light.

The first action of fermentation on the various sugars is, probably, to bring them all to the condition of grape sugar, and then decomposition into alcohol and carbonic acid ensues. In the same way the sugar of fruits is converted into the different wines, and other intoxicating drinks. The peculiar and characteristic taste of these different liquors is produced by the substances which are present with the sugar, and not by the fermented sugar itself. The amount of liquor produced must, of course, be in proportion to the sugar which the plant contains, but this is not the only circumstance which determines the plant or fruit to be selected. The manner and proportion in which the sugar is mixed with the other ingredients, is what chiefly determines the quantity and value of the liquor produced. Hence, though the sugar cane yields sugar far more abundantly than any other plant, and consequently may be made to produce the most liquor, yet the grape is selected as producing the best wine.

When the expressed juice of grapes, or *must*, is enclosed in a vessel out of contact of air, and subjected to the heat of boiling water, the small portion of oxygen present is rendered inactive, and the liquor does not ferment. But an exceedingly small portion of oxygen, even a single bubble, will start the fermentation, after which it will go on with or without the presence of air. The *mutual reaction* of the ferment, formed on the introduction of the bubble of oxygen,

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diagram. How is bread fermented and raised? To what is the peculiar and characteristic taste of the different liquors owing? How may fermentation be commenced in the expressed juice of cane? How is it then continued? What and the sugar of the grape juice, produces alcohol and carbonic acid, or, in other words, excites and continues fermentation. Yeasty particles are evolved and float in the liquid. If a solution of pure sugar be added, it is involved in the change, and portion after portion will disappear, but finally the yeast itself is exhausted, and then any excess of sugar remains unacted upon.

The *ferments*, or bodies which cause fermentation, are all nitrogenized bodies, since non-nitrogenized substances never spontaneously ferment. The *principle of fermentation* is considered to be a molecular disturbance, propagated from a body already in a state of decomposition, or a ferment. The complex organic body under these circumstances breaks up into inorganic bodies, and organic bodies of a composition more simple, and, consequently, possessing greater permanence.

All sweet substances pass spontaneously into fermentation without the necessity of adding to them a ferment, because they contain besides sugar, one of the nitrogenized substances, albumen, caseine, or gluten (408 and 410.) Thus from currants, gooseberries, beets, and grapes, wine is prepared, cider from apples, &c.

New beer holds some sugar and gluten in solution, therefore, like wine and cider, it undergoes, when kept, a second slight fermentation. If this is allowed to take place in well stopped bottles, so that the carbonic acid cannot escape, a foaming beer (bottled beer) is obtained. In the same way bottled cider and champagne are made.

358. The circumstances which promote the vinous fermentation, are the following:—(1.) *The presence of the proper quantity of active yeast.* If in the course of a slack fermentation the yeast subsides to the bottom, the fermentation ceases, but may be excited anew by stirring up the ingredients. (2.) *A certain degree of warmth.* This should not be less than 51° nor more than 86°. The temperature of 68° to 77° is the most favorable to the commencement and progress of the fermentation. Other circumstances being the same, the rapidity of the fermentation is proportional to the temperature within certain limits, so that by changing the

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do all the ferments contain? What is supposed to be the principle of fermentation? Why do all sweet substances pass spontaneously into fermentation? How are bottled cider, beer, and wine prepared? Why do these liquors foam on removing the cork?

358. Mention some of the circumstances which promote the vinous fermentation.

temperature, the action may be altered at pleasure. (3.) The fermentation proceeds the better and more equally *the greater the mass of fermenting liquor*, probably on account of the uniformly high temperature, as well as the uniform distribution of the active particles of yeast, by the greater energy of the movements of the liquid. (4.) *The presence of water.* When the saccharine solution is too much concentrated it does not ferment. Hence, very sweet musts furnish wines containing much undecomposed sugar. For a complete fermentative action, one part of sugar should be dissolved in ten parts of water.

359. Fermentation may be tempered or stopped :—(1.) *By those means which render the yeast inoperative.* This effect is produced particularly by oils that contain sulphur, as oil of mustard. It is produced also by sulphuric and sulphurous acids. (2.) *By the separation of the yeast.* This may be done by filtration or subsidence. (3.) *By lowering the temperature to about* 45°.

360. Pure alcohol is a colorless liquid, of pungent and agreeable taste and odor. At 60° its sp. gr. is 0·794 ; that of its vapor 1·613. When alcohol is obtained from sugar, carbonic acid escapes, carrying off a portion of the carbon and oxygen of the sugar. Alcohol, therefore, contains less carbon and oxygen than sugar, and consequently more hydrogen. To this is owing its lightness, its great inflammability, and its pale-bluish flame. This flame is free from smoke, and the products of its combustion are carbonic acid and water. Alcohol boils at 173°, and at a still lower point if slightly diluted with water, though the boiling point rises if the water be in greater proportion. It has never been frozen. Even at a cold of—148° it remains fluid. It is, therefore, excellently adapted for thermometers, by which great degrees of cold are to be measured. It is also used in the gas pipes of cities to prevent the freezing of the water which settles in them. The illuminating gas is made to pass through alcohol, by which not only is most of the steam withdrawn from the gas, but so much vapor of alcohol is also added to what remains, that the condensed liquid of alcohol and water in the gas-pipes does not freeze in winter. The specific gravity of alcohol varies with the amount of water present; hence its purity may be determined by ascertaining its density. It is miscible with water in all proportions, and has even a great attraction for it, absorbing its vapor from

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359. By what means may the vinous fermentation be regulated or stopped ?

the air, and abstracting the moisture from membranes and other similar substances immersed in it.

The flame of alcohol is of great use in chemical investigations, as it deposits no carbon or any other foreign substance on bodies exposed to its heat. Its solvent powers are also of great use, and it is employed to dissolve resins, oils, and other bodies not acted on by water. Wine, beer, &c., owe their intoxicating properties to the alcohol which they contain, the quantity of which in these liquors varies very much. Port and sherry, and some other strong wines, contain from 19 to 25 per cent. of alcohol, while in the lighter wines of France and Germany, it sometimes falls as low as 12 per cent. Beer, porter, &c., contain from 5 to 10 per cent.

361. *Brandy* is a constituent of all liquors containing alcohol, and, by itself, it is a mixture of of alcohol and water. If a little port wine, for example, be distilled at a moderate heat, brandy will be distilled over separate from the other constituents of the wine, and, by subsequent distillation at a still lower heat, the alcohol of the brandy may be separated from its water. It is, therefore, like alcohol, colorless in its pure state. Its ordinary yellow or red color is obtained from the coloring matter of the new oaken casks in which it is kept. A little burnt sugar is sometimes added to improve its tint, or to give it the desired color when it does not acquire a tint from the cask in which it is kept.

Each variety of alcohol has an aroma characteristic of the substance from which it was obtained, whether it be grapes, cherries, sugar cane, rice, corn, or potatoes. Even that from different growths of the vine may be distinguished.

362. *Rum* is distilled from the sugar cane. After most of the juice has been pressed out for making sugar, what still remains in the bruised cane is extracted by water, and this watery solution of sugar is fermented and produces rum. Both the fermenting and the flavoring principle reside chiefly in the fresh cane-juice, for they are dissipated to a great extent by boiling the sirup. Spirits distilled from West India molasses are perfectly free from any flavor of rum. Rum is yielded in very large quantities even from the *wash* of the cane, owing to the great amount of sugar which it contains.

363. *Gin* is distilled from rye. To every 100 gallons of

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360. Mention some of the properties of pure alcohol.

361. Of what is brandy composed? In what way may the difference between port wine, brandy, and alcohol be shown? To what is the color of brandy owing? What is sometimes added to improve its tint?

362. How is rum manufactured?

the liquor thus formed, two pounds of juniper berries, from three to five years old, are added, to which is owing the peculiar flavor of gin. About one-quarter pound of salt is added at the same time, and the whole is put into a still, and the spirit distilled over by a gentle and well regulated heat.

364. *Cider* is best obtained from bitter apples, which afford a denser juice, richer in sugar, which clarifies well, and when fermented keeps a long time. The juice of sweet apples is difficult to clarify, and that of sour apples makes bad cider. Late apples are in general preferred. After these are gathered, they are kept for about fifteen days to become mellow, which diminishes their mucilage, and develops alcohol and carbonic acid. The fruit should be gathered in dry weather. Much water is contained in the juice of apples. There is also found a little sugar analogous to that of the grape, a matter capable of causing fermentation in contact with the air, a pretty large proportion of mucillage, with malic and acetic acids.

SECT. I.—4. CONVERSION OF ALCOHOL INTO ETHER.

365. When an ounce of alcohol is mixed with an equal quantity of sulphuric acid, the latter takes from the alcohol 1 eq. of water, and the alcohol is converted into ether:

$C_4H_6O_2$=alcohol.

Divide this formula into C_4H_5O+HO.

C_4H_5O=ETHER.

(distilled from sulph. acid and alcohol.)

HO=WATER.

(unites with sulph. acid.)

Ether, when pure, is a colorless transparent liquid, of a peculiar taste and odor. Its specific gravity at 60° is about 0·720. It boils at 96°. At 46° below zero it freezes, and shoots into crystals. When dropped on the hand it occasions a sharp sensation of cold, from its rapid evaporation. It is more combustible, and burns with the evolution of more light than alcohol. It is exceedingly volatile, and the mixture of its vapor with the air is highly explosive. For this reason bottles containing ether should never be opened near

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363. How is gin obtained ?

364. What kind of apples afford the best cider ? Why are bitter apples to be preferred to sweet or to sour apples ?

365. How is alcohol converted into ether? State some of the properties of of ether.

a flame, as the mixed air and ether vapor within might explode and blow up the bottle. The same precautions should be observed with regard to alcohol, and the compounds of alcohol and turpentine (burning-fluid, spirit-gas, chemical oil, &c.) When ether vapor is mixed with oxygen and fired, it explodes with the utmost violence. When kept in an imperfectly stopped vessel, ether becomes acid, producing acetic acid by absorbing oxygen from the air. This attraction for oxygen is increased by elevation of temperature. Ether is miscible with alcohol in all proportions, but not with water. It dissolves only to a small extent in water (10 of water to 1 of ether,) and may be separated from alcohol by the addition of water. In this manner commercial ether may be examined. The solvent powers of ether are much less than those of alcohol or water. It is, however, of considerable use in organic chemistry in dissolving many oils and fatty substances. It also dissolves phosphorus to a small extent, and a few saline compounds, and some organic principles.

SECT. I.—5. ACTION OF HEAT ON VEGETABLE TISSUE.

366. Among the products obtained when wood is subjected to dry distillation, are: (1.) Charcoal, which remains behind after the volatile portions are driven off; (2.) A mixture of carburetted hydrogen, carbonic acid, and carbonic oxide gases, which are always produced in the manufacture of *illuminating gas;* (3.) Wood-vinegar, or pyroligneous acid; (4.) *Wood-tar*, a thick brown resinous liquid. Of these products, charcoal and illuminating gas have been already considered; wood-vinegar and wood-tar alone remain to be described.

367. *Wood-vinegar, pyroligneous acid.* One pound of dry beech wood yields nearly half a pound of pyroligneous acid. It its crude state it has a brownish black color, owing to the tar which it holds in solution, and a smoky odor, together with a very acid and disagreeable flavor. When purified it furnishes a strong acetic acid, which on account of its cheapness, is now much used in the preparation of acetates, particularly such as are employed in calico printing, and in dyeing. It possesses powerful antiseptic properties. Fresh beef dipped in pyroligneous acid in the summer season, for the space of only a minute, was perfectly

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366. Mention some of the products obtained by the distillation of wood.

sweet in the following spring. Fish were preserved by being sprinkled with salt, then drained and immersed in pyroligneous acid for a few seconds. The same effect is produced by soaking these substances in pyroligneous acid for a short time as by suspending them for months in smoke.

Wood-vinegar owes its antiseptic properties to a peculiar substance called *creosote;* one pound of wood-vinegar contains a quarter of an ounce of creosote in solution. Pure creosote is a colorless oleaginous liquid, gradually becoming brown by age, and of an oily consistence. It has a strong smell of smoke, and a burning taste, which disorganizes the tender skin of the tongue or the mouth. When taken internally it is a powerful poison. When applied for the toothache it is usually mixed with oil of cloves, and also with alcohol, otherwise its action would be too corrosive. No antidote is known to the poisonous effects of creosote, but its presence is easily detected after death by its peculiar and penetrating smell.

368. *Chloroform*, C_2HCl_3. When pyroligneous acid is very slowly distilled, a spirituous volatile liquid, very similar to brandy, first passes over, which is called *pyroxilic*, or *wood-spirit*. Chloroform is obtained by distilling wood-spirit with chloride of lime. It is a limpid, colorless liquid, volatile, and having a bland ethereal odor, and a hot, aromatic, sweet taste. Its density is 1·599, and it boils at 141°. It is nearly insoluble in water, and is not affected by concentrated sulphuric acid, but dissolves readily in alcohol and ether. It is lighted with difficulty, and burns with a green flame. Chloroform has extensive solvent powers, being capable of dissolving caoutchouc, gutta percha, lac, amber, and copal, substances which resist most other solvents. It also dissolves iodine, bromine, the organic alkalies, volatile oils, resins, wax, and fats. The principal use of chloroform is in medicine, where it is used both externally and internally. It is most commonly *inhaled*, when it produces a loss of consciousness, especially a total insensibility to the agents which ordinarily produce acute pain. This insensibility is generally produced in one or two minutes, and continues for five or ten minutes; but the effect may be kept up for many hours, by renewing the inhalation from time to time. The use of chloroform is followed by a drowsy state, or by quiet sleep,

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367. What is said of pyroligneous acid? To what does this acid owe its antiseptic properties? State some of the properties of creosote.

368. Write the composition of chloroform. How is this substance produced? Mention some of its properties;—some of its uses.

and no recollection is retained of anything that occurred during the state of insensibility. Bromine and iodine form two analogous compounds, *bromiform* C_2HBr_3 and *iodoform* C_2HI_3.

369. *Wood-tar* is of a resinous nature, being, like the resins, insoluble in water, though soluble in alcohol. It is very rich in carbon, as is, in some degree, indicated by its black color. On distillation it separates into a volatile oil (oil of tar,) and a black pitch, which is not volatile. When ships are calked or tarred, the tar undergoes a similar change, the oil volatilizes, and the pitch hardening in the pores of the wood, prevents the penetration of water. The wood is kept dry by this process, and, therefore, is less liable to decay. It is also preserved by the creosote which the tar contains.

SECT. I.—6. CONVERSION OF VEGETABLE TISSUE INTO HUMUS.

370. A *soil* may be considered as a magazine of inorganic matters, which are prepared by the plant to suit the purposes of its nutrition. Some soils, as those of new and alluvial countries, contain *vegetable matter* in large proportion, and as these have been found eminently adapted for the cultivation of most plants, their fertility has been ascribed to this organic matter in a state of decay. To this matter the term *vegetable mould*, or *humus*, has been applied. The chemical process which takes place in the decay of vegetable tissue, very much resembles those changes which wood undergoes in combustion, except that it takes place far more slowly. What is effected in combustion in minutes, is produced by decay only in the course of years. In combustion the constituents of the wood, by uniting with the oxygen of the air, are converted into carbonic acid and water. The same products are also formed in the decay of wood. In combustion, as well as in decay, the wood assumes a darker color, because, in both cases the hydrogen is oxidized more rapidly than the carbon, and the carbon which remains covers the burnt or decayed surface with first a brown and then a black color.

Plants grow more vigorously in a soil abounding in humus,

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369. What is said of wood tar?

370. What is the nature of a soil? What do the soils of new and alluvial countries usually contain? What is meant by the term humus? In what respects does the process of decay resemble that of combustion? Why do plants grow luxuriantly in a soil abounding in humus? Why does a great excess of hu-

because they find there carbonic acid and water, which are the products of the decomposition of vegetable mould, and which are indispensable to their growth. Humus exerts also a beneficial action upon vegetation, because it possesses the power of attracting moisture from the air, and of retaining it for a long time; and because, by means of the acids contained in it, it is able to abstract from the air, and also from manure, the third means of nutrition for plants —ammonia.

An injurious effect is however produced, when there is more than 50 per cent. of organic matter in the soil. In this case it becomes what is called *sour*, and produces nothing but poor wiry grass. In boggy and peaty soils the proportion is sometimes as high as 70 per cent. In such lands certain organic acids are generated, which are very injurious to plants. On the other hand, a soil that contains less than one-half per cent. of organic matter, will scarcely support vegetation. In the best soils the proportion does not average 5 per cent., and rarely exceeds 10 or 12. Oats and rye will grow upon land containing only 1 to 1½ per cent., barley where 2 or 3 per cent. are present, and good wheat soils contain in general from 4 to 8 per cent.; if very stiff and clayey, the proportion rises sometimes as high as 10 to 12 per cent.

The *amount* of humus, or decayed vegetable matter, in a soil, is not diminished but *increased* by vegetation, where the products of vegetation are not removed. Thus the leaves of forest trees, and other forms of vegetation, which are nourished chiefly by the carbonic acid of the atmosphere, and that conveyed to the plant through the roots with the rain-water in which it is dissolved, add an annual deposit of humus to the soil. The quantity of this, therefore, increases from year to year, if the ground is not disturbed, and this is the chief cause of the fertility of new lands.

SECT I.—7. OILS AND FATS.

371. The vegetable and animal fats agree so closely, that it will be convenient to consider them under one head. The vegetable fats are usually found in seeds or fruits; animal fats in a cellular membrane, called *adipose tissue*. The leaves of many plants are varnished on their upper surfaces with a

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mus produce an injurious effect. What effect has vegetation upon the amount of humus in a soil where the vegetation is not removed?

371. What is said of the sources of animal and vegetable fats? Into what

covering of wax and fat. Plants of the order cruciferæ (mustard, radish, water-cress, &c.,) are especially oil-bearing species. Oily bodies are divided into volatile and fixed. The former are capable of being distilled without decomposition; the latter are not. When dropped or spread on paper, they all leave a greasy stain, which disappears on applying heat, if caused by a volatile oil, but remains if produced by a fixed fatty substance. All these bodies have an attraction for oxygen, which, in some cases, is so great as to occasion spontaneous inflammation. Large masses of cotton and flax have taken fire from being moistened with rape or linseed oil (104.) The effect of this absorption of oxygen leads to a farther classification of the fixed oils into *drying* and *non-drying oils*, or those which become hard and resinous on exposure to the air, and those which thicken slightly, become sour and rancid, but never solidify. To the first class belong the oils used in painting, as linseed, rape, poppy-seed, and walnut; and to the second, olive and palm oils, and all the oils and fats of animal origin.

372. The fixed oils in general have but a feeble odor, and scarcely any taste. Whenever an oil possesses taste, it is invariably found to contain some volatile oily principle, as that of common butter. All the fixed oils are insoluble in water, and, with the exception of castor oil, but slightly soluble in alcohol. In ether, and in other essential oils, they dissolve in large quantity. The *consistence* of these substances varies from that of the thinnest olive oil to that of compact suet. This difference proceeds from the variable proportion in which the solid and fluid principles are associated in the natural products. All these bodies may in fact be separated by mere mechanical means, and by exposure to cold, into two or three different substances, which dissolve or mix with each other in all proportions. Thus olive oil exposed to a cold of 40°, deposits a large quantity of crystaline solid fat, which may be separated by filtration or pressure. This is termed *margarine*,* from its pearly aspect. That portion of oil which retains its fluidity at this, or even a greater cold, has received the name of *oleine*, or

* Latin, *margarita*, a pearl.

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are oily substances divided? What is said of the attraction of oils for oxygen? Into what two classes are the fixed oils divided?

372. Mention some of the properties of the fixed oils. What is margarine? —oleine?—stearine? In what way may these bodies be saponified? If the soap thus formed is decomposed by the addition of acid, in what state is the fat

elaine. Still another fatty principle has been obtained from *solid* animal fats, by pressure between the folds of blotting paper. The paper becomes impregnated with a permanently fluid oil, or oleine, while the solid part is found to consist of two solid fats, one resembling the margarine of olive oil, and the other having a much higher melting point, and other properties which distinguish it from that substance. This is called *stearine.*

When stearine, margarine, and oleine, are boiled with a strong solution of caustic potash or soda, they generally combine with these alkalies, and form soap. If acid be added to the soap thus formed, the acid takes the alkali and decomposes the soap. The fat which separates is found to have completely changed its character, having acquired a strong acid reaction when applied in the melted state to test-paper, and having become soluble with the greatest facility in warm alcohol. It is in fact a new substance, a true acid, capable of forming salts. This acid has been generated out of the elements of the neutral fat *under the influence of the base.* Stearine, when thus treated, yields *stearic acid,* margarine *margaric acid,* oleine *oleic acid.* Common animal fat gives a mixture of these three acids. Besides these acids produced in the process of saponification, a very peculiar sweet substance, called glycerine, remains in the solution after the acid has been removed.

373. *Stearine and stearic acid.* Pure stearine is most easily obtained by mixing purified mutton fat, melted in a glass flask, with several times its weight of ether, and suffering the whole to cool. Stearine crystalizes out while margarine and oleine remain in solution. The soft, pasty mass, may then be transferred to a cloth, strongly pressed, and the solid portion still further purified by recrystalization from ether. It is a white, friable substance, insoluble in water, and nearly so in cold alcohol. Boiling spirit takes up a small quantity, and boiling ether dissolves it very easily, but when cold retains only $\frac{1}{225}$ of its weight; hence, the process above given for obtaining stearine. The melting point of stearine, which is one of its most important physical character, is about 143°.

Stearic acid crystalizes from hot alcohol in milk-white needles, which are inodorous, tasteless, and quite insoluble, in

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obtained? How has the acid fat been produced? What three acids are in this way formed from stearine, margarine, and oleine? What substance remains in the solution after these acids have been withdrawn?

373. How is pure stearine most easily obtained? Mention some of its prop-

water. It is harder and more brittle than wax, and melts at 158°. It dissolves in its own weight of cold alcohol, and in all proportions at a boiling heat. It is also soluble in ether. Alkaline carbonates are decomposed by stearic acid. It may be volatilized in a vacuum without change. Stearine (stearic acid) candles are now manufactured on a large scale. They have become of late so popular, that large factories have been erected for their preparation. The wick of these candles is plaited upon a braiding machine, moistened with very dilute sulphuric acid, and dried. Wick prepared in this way is found to fall one side as it burns, and to consume entirely without requiring to be snuffed. The formula for stearic acid is $C_{68}H_{66}O_5$, 2HO.

374. *Oleine and oleic acid.* It is doubtful whether a perfectly pure oleine has yet been obtained; the separation of the last portions of margarine, with which it is always associated, is extremely difficult. Any fluid oil, animal or vegetable, which has been carefully decolorized, and filtered at a temperature approaching the freezing point of water, may be taken as a representative of this substance.

Oleic acid in its external appearance is hardly to be distinguished from olive oil, but it differs from this oil in having an acid taste and reaction, and in readily dissolving in cold alcohol. The oleic acid produced in stearic acid factories from tallow, as a secondary product, is frequently an article of commerce, being employed on account of its cheapness in the manufacture of soap, and in greasing wool for spinning. It melts at about 39°, and gives rise to a class of salts. The formula for oleic acid is $C_{36}H_{33}O_3$, HO. The following table contains the proportions of oleine and stearine in some of the most common fats:

	Oleine.	*Stearine.*
Fresh butter in summer,	60,	40.
" " in winter,	37,	63.
Hogs' lard,	62,	38.
Ox marrow,	24,	76.
Goose fat,	68,	32.
Duck fat,	72,	28.
Ox tallow,	25,	75.
Mutton suet,	26,	74.

375. *Margarine and margaric acid.* Margarine very

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erties;—of stearic acid. What use is made of stearic acid? Write the formula for stearic acid.

374. What is said of oleine?—oleic acid? Write the formula for oleic acid.

much resembles stearine; it is however more fusible, melting at 113°, and very much more soluble in cold ether. *Margaric acid* closely resembles stearic acid; it differs in its composition, has a lower melting point (about 140°), and is more soluble in spirit. Its composition is $C_{34}H_{33}O_3$, HO.

376. *Butyrine and butyric acid.* Common butter consists chiefly of a solid, crystalizable, and easily fusible fat, a fluid, oily substance, and a yellow coloring matter, besides mechanical impurities as caseine (409.) The oily part appears to be a mixture of oleine and a peculiar odoriferous principle, called *butyrine,* not yet isolated, which by saponification yields three distinct volatile acids, the *butyric,* the *capric,* and the *caproic.* These acids are easily separable by the unequal solubility of their baryta salts. *Caprylic and vaccinic* are the names of two other acids also found in butyrine. Butyric acid is a colorless, oily liquid of a sour taste, and an odor resembling old and rancid butter, in which it is probably present. It has a density of 0·963, dissolves in all proportions in water, acids, alcohol, ether, and oils, and readily distils without decomposition. Capric and caproic acids greatly resemble butyric in properties, but are less soluble in water.

377. *Wax.* Common bees-wax, freed from its yellow coloring matter by bleaching (p. 49), may be separated by boiling alcohol into three different principles, *cerine, merycine,* and *ceroline.* Cerine is a white, crystaline substance, soluble in about 16 parts of boiling spirit, and melting at 172°. This is more abundant than the other two principles. Merycine is much less soluble in alcohol, and melts at 162°.

Wax occurs in small quantities in all plants, especially in the shining coating of the leaves, stalk, and fruits. It is very apparent in the skin of apples, and the pollen of flowers. Some plants of Japan and South America contain large quantities of wax, and from these it is extracted by boiling and pressure. This is found in commerce under the name of *Japan wax.* The *wax myrtle* grows in almost all parts of the United States. The berries of this plant, which grow in clusters closely attached to the stems and branches, are covered with a coating of wax. These are boiled in water, and

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375. What is said of margarine and margaric acid? Write the formula of margaric acid.

376. Of what does butter consist? What is said of butyric, capric, and caproic acids?

377. Into what principles may wax be separated? What is said of cerine and merycine? What are some of the sources of wax?

the wax melting and floating on the surface, is either skimmed off and strained, or allowed to concrete as the liquor cools, and removed in the solid state. To render it pure, it is again melted and strained, and then cast into large cakes. It is collected in New Jersey, but more abundantly in New England, particularly Rhode Island, whence it is exported to other parts of the country.

378. *Cetine, spermaceti,* is obtained from the head of the spermaceti whale. The soft, solid matter found here is subjected to pressure, by which it is separated into a fluid oil, and a crystaline, brownish substance. The latter when purified, becomes the snow-white spermaceti of commerce. It melts at 120°, and, when cooled under favorable circumstances, forms distinct crystals. Boiling alcohol dissolves it in small quantity, and ether in much larger proportion. Cetine is saponified with great difficulty. Two products are obtained, *ethal* and *ethalic* acid. The first is a crystalizable fat, whose melting point is nearly the same as that of the spermaceti itself, but its solubility in alcohol is much greater. It is readily sublimed without decomposition. Ethalic acid resembles in many respects margaric acid. Cetine is composed of $C_{32}H_{32}O_2$.

Common oil contains a little mucilage, which it is extremely difficult to separate. This in burning, being a bad combustible, gathers around the wick and dims the light, rendering it necessary to trim all kinds of lamps more or less frequently. The purpose served by the wick of a lamp is, not merely to draw up the fluid, but to raise the temperature of the oil to that of combustion. In the coarser oils or fats, this elevation of temperature is not sufficient to consume them entirely, and hence, as in tallow candles, the soot is deposited on the wick. Wax is a better combustible than tallow, and, therefore, it burns with a smaller wick, so that the little foreign matter which gathers on the wick, weighs it down till it falls off together with the burnt part of the wick.

Fat forms about $\frac{1}{20}$ part of the weight of a healthy animal. It varies in consistence, color, and smell, according to the animals from which it is obtained. It is generally found flaccid in the cetaceous tribes, soft, and rank-flavored in the car-

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378. Whence is cetine obtained? Mention some of its properties. What two products are obtained by its saponification? What is said of ethal and ethalic acids? Write the formula for cetine. What impurity does common oil contain? What effect has this upon the combustion of the oil? What is the purpose served by the wick of a lamp? Why do not wax candles require

niverous, solid, and nearly scentless in the ruminants, usually white and copious in well-fed young animals, yellowish and more scanty in the old.

SECT. I.—8. VOLATILE OILS.

379. The odors of plants are due to the gradual evaporation of volatile oils, which are sometimes exceedingly diffused or diluted. Thus one hundred pounds of fresh roses or orange blossoms, contain scarcely a quarter of an ounce of the fragrant oil. These oils sometimes pervade the whole plant, and sometimes are confined to a single part. In some instances they are contained in distinct cellules, and in others formed upon the surface, as in many flowers, and exhaled as soon as they are formed. Occasionally two or more are formed in different parts of the same plant. Thus the orange tree produces one volatile oil in its leaves, another in its flowers, and a third in the peel of its fruit. In a few instances, when existing in distinct cellules, they may be obtained by pressure, as from the peel of the lemon and the orange, but they are generally procured by distillation with water.

Their boiling points are always higher than 212°, but at this temperature their vapor is so dense, that when carried over and condensed with the steam, a milky, or turbid liquid is obtained, which gradually separates into oil and water.

Sometimes the oil is heavier than water, and sinks to the bottom, and sometimes the reverse happens. A few are solid at the ordinary temperature, several become so at 32°, and many remain liquid considerably below this point. Heated in the air, the volatile oils take fire, and burn with a bright flame, attended with much smoke. Exposed at ordinary temperatures to the air, they absorb oxygen, assume a deeper color, and become thicker and less odorous. They are in this way ultimately converted into resin. This change takes place most rapidly under the influence of light.

When pure, the volatile oils are colorless, but they are, usually, yellowish and sometimes brown, red, green, and even blue, from the presence of impurities. They have a strong odor, resembling that of the plants from which they were procured, though generally less agreeable. Their

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to be trimmed? What part of the weight of a healthy animal is fat? What is said of the different kinds of fat?

379. To what are the odors of plants owing? In what state are these volatile oils? How are they generally procured? Mention some of the properties

taste is pungent and burning. They mix in all proportions with fat oils, and dissolve freely in both ether and alcohol. From alcohol they are precipitated by the addition of water. They resist saponification completely. Any fixed oil with which they may be adulterated, may be detected by putting a drop on paper. The grease spot will disappear, if the volatile oil is pure, on warming the paper, but if fixed oil be present the spot will remain. The volatile oils are very slightly soluble in water. When agitated with water they render it milky, and when they separate on standing the water still retains their odor and taste. This effect is produced in the highest degree when the oils or the plants from which they are obtained are distilled with water.

Like the fixed oils, the volatile oils consist of distinct principles, which are congealed at different temperatures, and may be separated by compressing the frozen oil between the folds of bibulous paper. The solid matter remains, within the folds, and the fluid is absorbed by the paper from which it may be separated by distillation with water. The solid portion is called *stearopten*, and the liquid *elaoptene*. The former often crystalizes out of certain volatile oils on standing. It differs in almost every case. The volatile oils are exceedingly numerous; some of the more common are arranged beneath in groups according to their constitution:

1. Volatile oils containing carbon and hydrogen:

Turpentine,
Citron,
Copaiva,
Storax,
Bergamotte,
Cubebs, &c.

2. Volatile oils containing carbon, hydrogen, and oxygen:

Bitter almonds,
Cajeput,
Lavender,
Rosemary,
Peppermint,
Cinnamon,
Pennyroyal,
Valerian,
Spearmint,
Camphor, &c.

3. Volatile oils containing sulphur:

Black mustard,
Horse radish,
Onions,
Asafœtida.

380. Class I. *Oil of turpentine*, $C_{20}H_{16}$, may be taken as a representative of this class. It is obtained by distilling

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of volatile oils. Of what two principles do volatile oils consist? How may these be obtained?

crude turpentine, which exudes from various pines and furs, or flows from wounds made for the purpose in the wood. This is now obtained chiefly from the woods of North Carolina and Virginia. During the winter months excavations of the capacity of about three pints are made in the trunk of the tree, three or four inches from the ground. Into these the juice begins to flow about the middle of March, and continues to flow throughout the warm season, slowly at first, rapidly in the middle of summer, and more slowly again in the autumnal months. The liquid is removed from these excavations as they fill, and transferred into casks, where it gradually thickens, and ultimately acquires a soft solid consistence. Very large quantities are thus annually produced, sufficient not only to supply the whole consumption of this country, but also to furnish a valuable export.

When this crude turpentine is distilled, the solid product left behind is common resin. When pure, oil of turpentine is perfectly limpid and colorless, of a strong, penetrating, peculiar odor, and a hot, pungent, bitterish taste. Its density, in the liquid state, is 0·865, and that of its vapor 4·764. It boils at 312°. Strong sulphuric acid chars and blackens this substance, and concentrated nitric acid and chlorine attack it with such violence, that inflammation sometimes ensues. With hydrochloric acid oil of turpentine forms a compound, which has been called *artificial camphor*, from its resemblance to that substance in odor and appearance. It is prepared by passing hydrochloric acid gas into the pure oil, cooled by a freezing mixture. After some time a white crystaline substance separates, which may be purified by solution in alcohol. The dark acid liquid from which the precipitate is separated, contains a similar but fluid compound. Different specimens of the oil of turpentine yield very variable quantities of these substances, which may perhaps arise from the existence of *two* very similar and isomeric oils in the ordinary article.

Oil of turpentine is very largely used in painting, and as a solvent for resins in making varnishes. These are made by dissolving resin in one of the volatile oils, generally turpentine, or in alcohol. As the varnish dries the turpentine evaporates, and the resin remains behind, and forms a hard coating, impervious to water. On account of its insolubility

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380. What do the oils of class first contain? Write the composition of the oil of turpentine. How is this oil obtained? What is the solid product left behind from the distillation of the crude turpentine? Mention some of the properties of the oil of turpentine;—some of its uses.

in water, resin may be precipitated from its alcoholic solutions by the addition of water, in the form of a dense white cloud.

381. Class II. The essential oils of this class are very numerous. Two of the most important of these are the oil of bitter almonds, and that of cinnamon.

Oil of bitter almonds is prepared in large quantities by distilling with water the paste of bitter almonds, from which the fixed oil has been expressed. It did not *pre-exist* in the almonds, being entirely wanting in the fat oil which is expressed from the fruit, but it is formed within the seed during the process of distillation. It may be purified by distillation with protochloride of iron and with hydrate of lime in excess. It is a colorless liquid of an agreeable odor, somewhat heavier than water. In water it is but slightly soluble, though very soluble in alcohol and ether. It boils at 356°. Pure bitter almond oil is probably not poisonous, but the common oil used to flavor puddings, custards, &c., often contains prussic acid (388), and is, therefore, highly dangerous. Its composition is $C_{14}H_6O_2$.

Oil of cinnamon is prepared from cinnamon of the best quality. This is crushed, infused twelve hours in a saturated solution of common salt, and the whole subjected to a rapid distillation ; water passes over milky with essential oil, which after a time separates. It is collected and left for a short time in contact with chloride of calcium, to remove completely the water. This oil is heavier than water and sinks to the bottom of the receiver in which the distilled products have been collected. Its composition is $C_{18}H_8O_2$. It is a fragrant and costly perfume.

Camphor is a solid oil or fat of this class. Like the other volatile oils it is vaporizable without change at a moderate heat, nearly insoluble in water, and soluble with facility in spirit. It is not confined to any one species or even genus of plants. Though not an abundant principle, it is widely diffused. It comes chiefly from Japan, where it is obtained from the wood of the *laurus camphora*, or camphor tree, by distillation with water in large iron pots, with earthen caps stuffed with straw. The camphor sublimes and concretes upon the straw. Small quantities have also been distilled from thyme,

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381. What is said of the essential oils of class second? How is the oil of bitter almonds prepared? State the properties of this oil. Write its composition. How is the oil of cinnamon prepared? State its properties, and write its formula. What is camphor? What are its properties? Whence is camphor obtained? Write its formula.

sage, and other aromatic plants. It is deposited in considerable quantities by some volatile oils after long standing.

Camphor possesses a very singular reaction with water and with the other volatile oils. If a small piece be placed on the surface of a basin of pure water, it will immediately begin to move round with great rapidity, but a single drop of any odoriferous liquid poured into the basin, will instantly stop this motion. Camphor contains $C_{20}H_{16}O_2$.

382. Class III. *Oil of black mustard* is obtained by distillation from black mustard seed, or the unripe grains or corns of pepper. The volatile oil does not pre-exist in the seed, but is formed during the distillation. When pure, the distilled oil is colorless, and has a most powerful and suffocating smell, and a density of 1·015. It boils at 289°. Water dissolves it in small quantity, and alcohol and ether very freely. The oil itself, at a higher temperature, dissolves both sulphur and phosphorus, and deposits them in a crystaline form on cooling. It is oxidized with violence by nitric acid and by aqua-regia. Alkalies decompose it by the aid of heat. Mustard oil contains $C_8H_5NS_2$.

SECT. I.—9. RESINS AND BALSAMS.

383. Common resin or colophony, furnishes, perhaps, the best example of this class. It contains three bodies having acid properties, called *pinic*, *sylvic*, and *pinaric acids*. Pure sylvic acid crystalizes in small, colorless, rhombic prisms, insoluble in water, soluble in strong and hot alcohol, in volatile oils, and in ether. It melts when heated, but cannot be distilled without decomposition. The properties of pinic acid are similar. Both these have the same composition, $C_{40}H_{30}O_4$. Pinaric acid is also isomeric with the preceding acids.

White resin is the residue which remains from the evaporation of turpentine. In this process two different operations are going on at once; a part of the volatile oil of the turpentine evaporates, and occasions the peculiar smell of the pine forests, but another part attracts oxygen from the air, and is converted into resin.

384. *Lac* is a substance very similar to wax in the manner of its formation; it is the product of an insect which collects its

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382. How is the oil of black mustard obtained? What is said of this oil? Write its formula.

383. What three acids does common resin contain? What is said of sylvic and pinic acids? Write the composition of these acids. How is white resin obtained?

ingredients from flowers. It is formed into cells, fabricated with as much skill as those of the honey comb, but differently arranged. It is a very valuable resin, much harder than colophony, and easily soluble in alcohol. Lac is used in varnishes and in the manufacture of hats, and very largely in the preparation of sealing wax, of which it forms the chief ingredient. Crude lac contains a red dye, which is partly soluble in water. A hot solution of borax dissolves lac in considerable quantity. By rubbing India ink in this solution, a *label ink* may be formed, which will be unaffected by acid vapors, and, when once dry, becomes nearly insoluble in water.

385. *Caoutchouc, India rubber*, is a milk white juice which exudes from several large trees of South America and the East Indies. The *ficus elasticus* or the caoutchouc tree of Assam, is larger than any other tree in the extensive forest where it abounds, and may be distinguished from the other trees at a distance of several miles, by its dense, huge, and lofty crown of foliage. The main trunk of one which was carefully measured, was found to have a circumference of no less than 74 feet, and, as this tree is one of the banyan family, the girth of the main trunk, with the supports immediately around it, was 120 feet. The area covered by the expanded branches, had a circumference of 610 feet. The height of the central tree was 100 feet. Of these trees it is estimated that there are no less than 43,240, within a length of 30 miles, and breadth of 8 miles of forest, near Ferozepoor in Assam. Though the geographical range of this tree in Assam is confined to a few degrees of latitude, it occurs on the slopes of hills, up to an elevation of probably 22,500 feet. Incisions are made in the tree through the bark to the wood, all around the trunk, and also the large branches up to the very top of the tree, the quantity which exudes increasing with the height of the incision. The juice is better when drawn from old than from young trees, and richer in the cold season than in the hot. It may be safely extracted once every fortnight, but the bleeding is generally confined to the cold months, in order not to obstruct the vigorous vegetation of the tree in the hot months. About 46 lbs., or somewhat more, is reckoned as the average product of each bleeding of one tree, or 1,978,000 lbs. for 43,000 trees. This juice is composed of about half caoutchouc and half water. As it trickles from the incisions, it is collected in clay moulds of

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384. What is said of lac? Mention some of its uses.
385. Whence is caoutchouc obtained? What is said of the caoutchouc tree?

various forms. A layer adheres to the clay, and dries on it, and several layers are successively added. When sufficient thickness has been obtained, the mould is broken up, and shaken out of the solid caoutchouc. In this country, and in England, it is cut up, and manufactured into a great variety of articles. Its dark color is produced by being smoked. It is softened but not dissolved in boiling water, and is also insoluble in alcohol. In pure ether, rectified native naptha, and petroleum (coal tar), it dissolves, and is left unchanged on the evaporation of the solvent. Hence, in making India-rubber cloth, two surfaces of cloth are cemented together with a varnish made of caoutchouc dissolved in one of these liquids, and this forms a compound impervious to air and water. The caoutchouc is also sometimes dissolved in oil of turpentine, which forms a viscid adhesive mass, drying but imperfectly. At a temperature a little above the boiling point of water, caoutchouc melts, but never afterwards returns to the firmer elastic state. Few chemical agents affect this substance; hence its great use in the practical operations of chemistry. Bags of it soaked in ether until they become gelatinous, may be distended by blowing to a very great size, and thus become useful for a great variety of purposes. When caoutchouc thread is used in the loom, it is necessary that its elasticity should be removed until it is woven, and then restored. The thread is rendered inelastic and finer by the same process. It is first soaked in a tub of cold water, and then softened in hot water, and finally wound upon a reel turned quickly, while the operator stretches the caoutchouc with his hand, so that its length is increased 8 or 10 times. The reels when thus filled, are placed during some days in a cold apartment, where the thread becomes firm. This process renders the threads inelastic, but their elasticity when woven is easily restored by passing a hot smoothing iron over the tissue laid upon a table covered with blanket stuff. Ropes are sometimes made of the strongest of these threads braided with hemp. These ropes possess, after their elasticity is restored, a strength double that of cordage of like diameter.

For the method of uniting sheet India-rubber, see Appendix, under the head of "chemical processes."

Threads of caoutchouc are readily united by paring the

How is the juice obtained? How is its dark color produced? What are some of its properties and uses? How is caoutchouc manufactured into thread and cloth?

ends obliquely with scissors, and then pressing them together, taking care to admit no grease or moisture within the line of junction.

386. *Gutta percha* is produced from several trees in the East Indies, especially from the tree called *percha*, found in the island of Singapore, and the countries adjacent. This tree is of considerable magnitude, with a trunk commonly three feet, and sometimes as much as six feet in diameter. The natives procure the gutta percha by the very wasteful mode of cutting down the tree, stripping off the bark, and then collecting the milky juice. Twenty or thirty pounds are thus collected from each tree. A much greater quantity would probably be obtained by simply tapping the tree, and thus preserving it for a future supply. This juice, like caoutchouc, coagulates on exposure to the air, and has the advantage over the latter substance, that, though quite hard when cold, it becomes soft and plastic by moderate heating.

Gutta percha has a dull white or whitish color, and a feeble odor. It is tasteless, hard, almost horny at ordinary temperatures, somewhat flexible in thin pieces, and very tenacious. At about 120° it becomes softer and more flexible; at 150° or 160° it is soft, very plastic, and capable of being welded and moulded into any form. In the softened state, which may be produced by hot water or by dry heat, it is readily cut with a knife, though with some difficulty when cold. Exposed to a heat of 330°, it loses a portion of water, and on hardening becomes translucent and gray; but it recovers its original properties if immersed in water. Heated in an open vessel it melts, foams up, and takes fire, burning with a brilliant flame and with smoke.

By different processes gutta percha is made elastic like caoutchouc, hard like marble, and fit to spread on cloth, thick or thin. A table slab has been made of it, and long used without injury, having the external qualities of polished marble. Utensils of various kinds, medallic and other ornamental impressions, casts, sheets, bands, cords, tubes, &c., may be made of it with great facility. It has also been introduced into surgery, in order to preserve limbs and joints in fixed positions. For this purpose gutta percha bands are prepared, two or three inches broad and $\frac{1}{12}$ of an inch thick, which are first softened in warm water, and then applied to the limb. These bands soon harden, and form a

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386. Whence is gutta percha obtained? Mention some of its properties and uses. Write the composition of gutta percha and caoutchouc.

firm case for the limb. If a solution of gutta percha in bisulphuret of carbon is spread over a wound, the liquid will soon evaporate, and the gutta percha hardening will form a protection to the wounded part. One of the most important of the uses of gutta percha is in covering telegraph wire, especially where this wire is conveyed under water. Its composition and that of caoutchouc are nearly alike:

	Carbon.	*Hydrogen.*	*Specific gravity.*
Gutta percha,	87·8,	12·2,	0·9791.
Caoutchouc,	87·2,	12·8,	0·9355.

SECTION II.—THE AZOTIZED PRINCIPLES.

SECT. II.—1. CYANOGEN, FULMINIC ACID.

387. *Cyanogen*, C_2N, is prepared by heating cyanide of mercury (390.) to redness. This salt is decomposed into metallic mercury, and a colorless, inflammable gas, called cyanogen. It has a pungent and peculiar odor, and burns with a beautiful purple, or peach blossom flame. At the temperature of 45°, by a pressure of 36 atmospheres, it condenses to a thin, colorless, transparent liquid. Water absorbs 4 or 5 times its volume of this gas, and alcohol a much larger quantity, but the compound thus formed is rapidly decomposed. Its specific gravity is 1·806, its symbol Cy.

Cyanogen, though a compound, like the organic radicals (p. 232) unites with the *elements exactly in the same manner as though it were an element.* Though not a simple body in its composition, yet as it is simple in all its relations, it may be considered as coming under the third law of affinity, p. 61, "that simple bodies unite only with simple and compound with compound bodies." In its relations to other bodies, it is so closely related to the elements chlorine, iodine, bromine, and fluorine, that it is sometimes classed with these bodies. Like these bodies it forms with hydrogen an acid, *hydrocyanic* or *prussic acid*, and like them also it unites with the metals forming protocyanides and percyanides.

388. *Hydrocyanic or prussic acid*, HCy, or $H+C_2N$.

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387. Write the symbol of cyanogen. How is this gas prepared? Mention some of its properties. Is cyanogen an exception to the law that simple bodies unite with simple bodies and compound with compound bodies? To what elements is it closely related?

Anhydrous prussic acid is a thin, colorless, and very volatile liquid, which exhales a very strong odor of peach blossoms. Its density at 45° is 0·7058. It boils at 79°, and solidifies when cooled to zero. Its reaction is feebly acid, and it mixes with water and alcohol in all proportions. It is one of the most formidable poisons known, and even when largely diluted with water, its effects on the animal system are exceedingly energetic. It is employed, however, in medicine in very small doses. Its odor is so strong as to produce immediate headache, and its vapor cannot be inhaled without the greatest danger. Ammonia and chlorine are the best antidotes, but the poison is often fatal before these can be obtained.

Pure hydrocyanic acid cannot be preserved, even in well stopped bottles. After a very short time it grows dark, and eventually deposits a black substance, containing carbon, nitrogen, and perhaps hydrogen ; ammonia is formed at the same time, and probably other products. Light favors the decomposition. It volatilizes so rapidly that a drop of it held on the end of a glass rod, becomes solid by its own evaporation. Though usually a product of art, this acid exists in, or is formed during the distillation of the cherry laurel, bitter almond, bird cherry, peach, and some other plants. It may be detected by its smell, and by its yielding a precipitate of Prussian blue, when acted on in solution successively by sulphate of iron, potash, and an excess of hydrochloric acid. If the liquid in which the poison is supposed to exist be acidulated with sulphuric acid and distilled, the prussic acid will be found in the first portions which come over.

389. *Cyanide of potassium*, KCy, may be formed by the direct union of cyanogen and potassium, or by igniting ferrocyanide of potassium (391.) in a close vessel. For common purposes in the arts, as in electro-plating and gilding, where a little impurity is of no consequence, it may be formed by mixing 8 parts of ferrocyanide of potassium, rendered anhydrous by heat, with 3 of carbonate of potash also dry, and fusing the mixture in a crucible, with occasional stirring, until gas ceases to be evolved, and the fluid portion of the mass becomes colorless. The crucible is left at rest for a few moments, and then the clear fluid decanted off from the heavy black sediment at the bottom, which is principally metallic iron in a state of minute division.

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388. Write the symbol of prussic acid. What are the properties of this acid ? What are the best antidotes to its poisonous effects ? Where does prussic acid occur naturally ? How may it be detected ?

Cyanide of potassium forms colorless, cubic or octahedral, anhydrous crystals, deliquescent in the air, and exceedingly soluble in water. It dissolves in boiling alcohol, but separates in a great measure on cooling. It is readily fusible, and undergoes no change at a moderate heat, or even at a white heat when air is excluded. If air be present, oxygen is absorbed, and the cyanide of potassium becomes cyanate of potash. Its solution has an alkaline reaction. All acids decompose this salt, even the carbonic acid of the atmosphere, to which is owing the smell of hydrocyanic acid, which it emits when exposed to the air. Cyanide of potassium is exceedingly poisonous, acting precisely like prussic acid. The tenth of a grain of the salt killed a small bird in the space of a minute ; a solution of five grains destroyed a large dog in a quarter of an hour. As a medicine, it is considered applicable to all cases in which hydrocyanic acid has been found useful. Cyanide of potassium has highly important uses in chemical analysis.

390. *Cyanide of mercury*, HgCy. One of the most remarkable properties of cyanogen is its powerful attraction for certain of the less oxidable metals, as silver, and more particularly mercury and palladium. Dilute hydrocyanic acid dissolves finely powdered red oxide of mercury with the utmost ease, the liquid loses all odor, and yields on evaporation crystals of cyanide of mercury. Cyanide of potassium is also decomposed by red oxide of mercury, the cyanogen passes to the mercury forming cyanide of mercury, and the oxide of potassium or potash is left in the state of a hydrate. Generally, however, this salt is prepared from ferrocyanide of potassium. Of the ferrocyanide, 2 parts are dissolved in 15 parts of hot water, and 3 parts of dry sulphate of mercury added. The whole is boiled for 15 minutes, and filtered hot from the oxide of iron which separates. The filtered solution on cooling deposits the new salt in crystals. It forms white, translucent prisms, much resembling those of corrosive sublimate, which are soluble in 8 parts of cold water, and in a much smaller quantity of hot water. They are also soluble in alcohol. The solution has a disagreeable, metallic taste, and is very poisonous.

391. *Ferrocyanide of potassium*, 2KCfy+3HO. The symbol Cfy, is that of a body not yet described, called *ferro-*

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389. Write the symbol of cyanide of potassium. How may this substance be prepared ? Mention some of its properties ;—its uses.

390. Write the symbol of cyanide of mercury. How is this cyanide prepared ? Mention some of its properties.

cyanogen. When a solution of cyanide of potassium is digested with iron filings at a gentle heat in an open vessel, oxygen is absorbed from the air, and the iron dissolves quietly and disappears. A highly alkaline, yellow liquid is obtained, which, on evaporation, leaves lemon-yellow crystals, containing potassium in combination with a new salt-radical, which is composed of the metal iron (Latin *ferrum*) and the elements of cyanogen, and hence called ferro-cyanogen.

On the large scale, ferrocyanide of potassium is made by igniting carbonate of potash and iron filings in an iron vessel with presence of air, from which nitrogen is obtained. Animal matter is also sometimes added to supply nitrogen. The mass after ignition, is acted upon by hot water, which dissolves out a large quantity of the cyanide of potassium, which is converted into the ferrocyanide by the iron. The hot solution is filtered, and on cooling yields large, transparent, lemon-colored crystals of the ferrocyanide of potassium. These crystals are four-sided, tabular, derived from an octahedron with a square base. They cleave with facility in a direction parallel to the base of the octahedron, and are tough and difficult to powder. They dissolve in 4 parts of cold and 2 of boiling water, and are insoluble in alcohol. They are permanent in the air, and have a mild, saline taste. The commercial salt is slightly poisonous, but the pure salt is unproductive of harm in the dose of several ounces. By a gentle heat it loses 3 eq. of water, and becomes anhydrous. It is a chemical reagent of great value. When mixed in solution with neutral or slightly acid salts of the metals, it gives rise to precipitates which very frequently present highly characteristic colors. Some of these are given in the following table :

Metal.	*Precipitate.*	*Metal.*	*Precipitate.*
Iron, protoxide,	white.	Palladium,	olive.
" deutoxide,	pale-blue.	Silver,	white, changing to blue.
" (peroxide),	deep-blue.	Nickel,	apple-green.
Copper, protoxide,	white.	Cobalt,	grass-green.
" deutoxide,	deep-brown.	Titanium,	reddish-brown.
Platinum, . . .	yellow.	Uranium,	blood red.

Gold, Mercury (deutoxide), Lead, } White.
Tin, Zinc, Manganese, Antimony,
Cadmium, Bismuth, Cerium,

392. *Ferricyanide of potassium,* $3K + Cfdy$, is supposed

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391. Write the composition of ferrocyanide of potassium. In this formula what does Cfy denote ? How is this cyanide prepared ? What are its properties ?

to be composed of 3 eq. of potassium, and one of a new salt-radical, called *ferri*, or *ferridcyanogen*, whose symbol is Cfdy, and which has never been isolated. It forms regular, prismatic, and sometimes tabular crystals, of a beautiful ruby-red tint, permanent in the air, and soluble in 4 parts of cold water. The solution has a dark greenish color. The crystals burn when introduced into the flame of a candle, and emit sparks. Its solution with peroxide of iron yields a blood red color.

393. *Sulphocyanide of potassium*, KCsy. The elements of cyanogen combine with sulphur, forming a well defined salt-radical, called *sulphocyanogen*, which contains C_2NS_2, and is expressed by the symbol Csy. It crystalizes in long, slender, colorless prisms, or plates, which are anhydrous. It has a bitter, saline taste, and is not poisonous. It is very soluble in water and alcohol, and deliquesces when exposed to a moist atmosphere. When heated, it fuses to a colorless liquid, at a temperature far below that of ignition. This salt is the most delicate test known for iron when in the state of peroxide.

394. *Fulminic acid*, Cy_2O_3+2HO, is known only in combination. Some of its salts are characterized by the violence with which they detonate from a very slight disturbance.

Fulminate of silver, $2AgO, C_4N_2O_2$, is prepared by dissolving 40 or 50 grs. of silver, which need not be pure, in ½ oz., by measure, of warm nitric acid (sp. gr. 1·37.) To the solution, while still hot, add two measured ounces of alcohol, and apply heat until reaction commences. The fulminate of silver slowly separates from the hot liquid in small, crystaline plates, which are washed with a little cold water, distributed upon separate pieces of filter paper in portions not exceeding a grain or two each, and left to dry in a warm place. When dry, the papers are folded up and preserved in a box or bottle. This is the only safe method of keeping the salt. Fulminate of silver is soluble in 36 parts of boiling water, but the greater part crystalizes out on cooling. It explodes with wonderful violence with concentrated sulphuric acid, and when strongly heated, or when rubbed or struck with a hard body. The metal is reduced, and a large

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392. Write the composition of ferricyanide of potassium. In the formula what does Cfdy denote? What are the properties of this substance?

393. Write and explain the formula for sulphocyanide of potassium. Mention some of its properties.

394. Write and explain the composition of fulminic acid;—fulminate of silver. How is this salt prepared? What are its properties? Write and ex-

amount of gaseous matter liberated. Notwithstanding its explosive energy when alone, if cautiously mixed with oxide of copper, it may be burned in a tube, with as much facility as any other organic substance.

Fulminate of mercury, $2HgO, C_4N_2O_2$, is prepared by a process very similar to that by which the silver salt is obtained. One part of mercury is dissolved in 12 parts of nitric acid, and the solution mixed with an equal quantity of alcohol, gentle heat is applied, and, if the reaction becomes too violent, it is moderated by the addition from time to time of more spirit. The fulminate of mercury separates from the hot liquid, and after cooling may be purified from an admixture of reduced metal by solution in boiling water and recrystalization. It much resembles the silver salt in appearance and properties. It explodes violently by friction or percussion, but merely burns with a sudden and almost noiseless flash when kindled in the open air. It is manufactured on a large scale for the purpose of charging *percussion caps*. One of these contains only one third of a grain of fulminate of mercury; sulphur and chlorate of potash are added (209.), and the powder pressed into the cap secured by a drop of varnish.

SECT. II.—2. VEGETABLE ALKALIES.

395. The vegetable alkalies constitute an extensive class of bodies, which are, for the most part, the active medicinal agents of the plants in which they occur. They are generally sparingly soluble in water, but more soluble in boiling alcohol, from which they crystalize in a very beautiful manner on cooling. The taste of these substances is intensely bitter, and their action on the animal economy exceedingly energetic. They all contain a considerable quantity of nitrogen, and are very complicated in constitution, having high combining numbers. Morphia, narcotine, cinchonia, quinine, strychnia, and brucia, belong to this very numerous class of bodies.

396. *Morphia*, $C_{34}H_{19}NO_6, +2HO$, is the chief active principle of opium, and the most characteristic type of this group of bodies. When crystalized from alcohol, morphia

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plain the formula for fulminate of mercury. State the process by which it is prepared and mention its properties. What are some of its uses?

395. What is said of the vegetable alkalies?

396. Write the composition of morphia. Where is this substance found? Mention some of its properties.

forms small but very brilliant, prismatic crystals, which are transparent and colorless. Exposed to a moderate heat it loses the crystaline form, becoming white and opaque. At a higher temperature it melts, inflames like resin, and leaves a small quantity of charcoal, which easily burns away. It is dissolved by the fixed and volatile oils. At least 1000 parts of water are required for its solution, which tastes slightly bitter, and has an alkaline reaction. These effects are much more evident in the alcoholic solution. It dissolves in about 30 parts of boiling alcohol, but the greater part crystalizes from the solution upon cooling. In dilute acids it dissolves with great facility, and it is also dissolved by excess of caustic potash or soda, but scarcely by excess of ammonia. In powder, morphia strikes a deep bluish color, with a neutral persalt of iron, decomposes nitric acid with liberation of iodine, and forms a deep yellow or red compound with nitric acid.

397. *Cinchonia*, $C_{20}H_{12}NO$, and *quina*, $C_{20}H_{12}NO_2$, are contained in Peruvian bark, and give to it its valuable properties. They are associated in the bark with sulphuric acid, and a special acid not found elsewhere, called the *kinic*. Cinchonia is contained in the largest quantity in the pale bark, quina in the yellow bark, and both are contained in the red bark.

Pure cinchonia crystalizes in small but beautifully brilliant, transparent, four sided prisms. It is but little soluble in water (in 2500 parts.) It is very soluble in boiling alcohol, which deposits a portion in the crystaline state upon cooling. It is slightly soluble in ether and the fixed and volatile oils. Its alkaline character is very decided, as it neutralizes the strongest acids, forming with them saline compounds. At first it appears to have but little taste, but in a short time this is developed by the solution of a minute portion in the saliva. Its salts are intensely bitter.

398. *Quina*, or *quinine*, much resembles cinchonia. It does not crystalize so well, and is much more soluble in water. By cautious management it may be crystalized in pearly, silky needles. It is fusible like the resins, and becomes brittle on cooling. Its taste is intensely bitter.

Sulphate of quinine is manufactured on a large scale for medicinal uses. It crystalizes in fine, silky, slightly flexible needles, interlaced among each other, or grouped in small star-like tufts. Its taste is intensely bitter. It is very slightly

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397. Write the composition of cinchonia. Whence is this substance obtained? What are its properties?

398. What is said of quina?—sulphate of quinine?

soluble in water, and the solution is neutral. Its solubility is much increased by the addition of a little sulphuric acid. This salt has the same action on the system as Peruvian bark, without being so apt to produce nausea and other bad effects. It may, therefore, be substituted for that remedy in most diseases to which the latter is applicable.

399. *Strychnia*, $C_{44}H_{24}$, N_2O_8, is contained in *nux vomica*, and several other plants. Under favorable circumstances, it crystalizes in small, but exceedingly brilliant, octahedral crystals, which are transparent and colorless. Rapidly crystalized, it is in the form of a white powder. It is but slightly soluble in water (in 7000 parts), and so intensely bitter, that it communicates a sensible taste to 600,000 parts of water. It dissolves in hot and somewhat dilute spirit, and in volatile oils, but neither in absolute alcohol, ether, nor a solution of caustic alkali. It is one of the most violent poisons known. It is sometimes used as a medicine, but unless it is employed in exceedingly small quantities it acts with fearful energy, causing lock-jaw immediately, and death in a very short time. Half a grain blown into the throat of a rabbit proved fatal in five minutes.

SECT. II.—3. ORGANIC COLORING PRINCIPLES.

400. Few plants contain colors that are permanent when exposed to the air and sun. Most of the beautiful tints of flowers fade and disappear soon after the flowers are gathered, and the coloring matter is so minute, that it is impossible to extract it by pressure, or so evanescent that it cannot be long preserved. We find, however, in a few instances, sometimes in the roots or the wood, and sometimes in the leaves, a coloring juice of greater permanence and density, which may be extracted and employed for coloring other substances. This is extracted generally by water, but sometimes by alcohol or other liquids. All the organic coloring principles are of vegetable origin, except cochineal. The *art of dyeing* is founded upon an affinity, or attraction, existing between the coloring matter of the dye and the fibre of the cloth. In woolen and silk, this affinity is usually very considerable, and to such tissues a permanent stain is com-

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399. Write the composition of strychnia. Whence is this substance obtained? What are its properties?

400. Why cannot most of the vegetable colors be preserved? How are those coloring matters which are more permanent usually extracted? What is the only coloring matter of animal origin? Upon what is the art of dyeing found-

municated, but with cotton or flax it is much weaker. To render the color permanent in these cases, a third substance is employed, which possesses a high degree of affinity, both for the fibre of the cloth and the coloring matter. Alumina, peroxide of iron, and oxide of tin, are usually employed for this purpose. With these substances the cloth is first impregnated, and afterwards colored with the dye. An insoluble substance is thus formed in the fibre of the cloth. The same substance may be formed by precipitating some colored infusion, as an infusion of logwood, with a little alkali, by alum. The precipitate consists of alumina, in combination with the coloring matter. This combination is called a *lake*. When this compound is formed within the fibre of the cloth, a permanent dye is effected. Alumina, peroxide of iron, and other bodies which are employed to render colors permanent, are called *mordants* (251.) Oxide of iron gives rise to dull, heavy colors; alumina and oxide of tin, especially the latter, to brilliant ones. By applying the mordant *partially* to cloth, by a wooden block or otherwise, a pattern may be produced, for the color will be permanent only where the mordant is applied, and may be washed out of the other part.

401. *Indigo* is rendered, by the addition of mordants, the most important of the vegetable colors. Without mordants it gives a color that is soon lost, and hence, before the use of these substances was known, in the reign of Queen Elizabeth, indigo and logwood were forbidden to be used as dyes. By an act of parliament, the dye-houses were searched, and these two substances when found were burnt. This act remained in full force till the time of Charles II, or for a century.

Indigo is the product of several plants of the genus *indigofera*, which grow principally in warm climates. When the leaves of these plants are placed in a vessel of water and allowed to ferment, a yellow substance is dissolved out, which, by contact of air, becomes deep blue and insoluble, and finally precipitates. This, when washed and carefully dried, forms the indigo of commerce. It is not contained in the plant, but is produced by the oxidation of some substances there present. The best indigo is so light as to swim upon water ; its powder has an intensely deep blue tint. It

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ed ? What is the strength of this attraction in wool and silk ?—in cotton and flax? How do mordants render colors permanent ?

401. What is said of the history of indigo ? Why was indigo forbidden to be used ? How is it now rendered a permanent color ? What are the sources of indigo ? How is it prepared from these plants ? Mention some of its proper-

may be freed from its impurities, which usually constitute at least half of its weight, by being powdered and boiled in dilute acid, in alkali, and afterwards in alcohol.

Pure indigo is quite insoluble in water, alcohol, oils, dilute acids, and alkalies. It dissolves in about 15 parts of concentrated sulphuric acid, forming a deep blue, pasty mass, entirely soluble in water, and often used in dyeing. In contact with deoxidizing agents, and with an alkali, indigo suffers a remarkable change; it becomes soluble and nearly colorless, perhaps returning to the same state in which it existed in the plant. On this principle the dyer prepares his indigo vats. Five parts of powdered indigo, 10 of protosulphate of iron, 15 of hydrate of lime, and 60 of water, are agitated together in a close vessel and allowed to stand. The hydrated protoxide of iron in conjunction with excess of lime, reduces the indigo to the soluble state; a yellowish liquid is produced, from which acids precipitate white or *deoxidized* indigo, which absorbs oxygen with the greatest avidity when brought in contact with the air. Cloth steeped in the yellow solution, and then exposed to the air, acquires a deep and most permanent blue tint, by the deposition of solid, insoluble indigo *in the substance of the fibre.* Instead of the iron, the salt, and the lime, a solution of caustic soda and grape sugar may be used. The sugar becomes oxidized and the indigo reduced in the deoxidized state.

When the cloth is previously boiled in alum mordant, and then in a bath of indigo, mixed with any of the yellow dyes, a *green* color is obtained. *Wool* may be dyed *violet, purple,* or *lilac,* by means of cochineal, mixed with sulphate of indigo. The same colors are given to silk, by first dyeing crimson with cochineal, and then dipping the silk into the indigo bath. *Cotton and silk* are first dyed blue, then galled (with nutgalls), and soaked in a decoction of logwood; but a more permanent color is given by means of oxide of iron. *Ivory* is dyed blue by being immersed a longer or shorter time in a dilute solution of sulphate of indigo mixed with a little potash. It assumes a blue tint of greater or less intensity, according to circumstances. Blue combined with red and yellow in cloth produces *olive.* Blue insoluble indigo, is composed of $C_{16}H_5NO_2$, and white, or reduced indigo, of

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ties. What change does indigo undergo in contact with deoxidizing agents and with alkalies? In what way does the dyer prepare his indigo vat? How do cloths steeped in this solution attain a deep and permanent blue? How is a green color obtained? How is wool dyed violet, purple, or lilac? Write the composition of blue indigo;—of white indigo.

$C_{16}H_6NO_2$. Under the action of heat and of reagents, indigo yields an exceedingly numerous class of bodies.

402. *Litmus* is one of the colors employed by the dyer. To the chemist it is a reagent for acids, by which it is instantly reddened; it then becomes a test for alkalies, by which its blue color is restored. It is prepared from a lichen that grows on maritime rocks, most abundantly in the Canary and Cape Verd Islands. It is also prepared from a plant which is collected in Norway. It comes in friable, violet colored, finely granular pieces. It has an alkaline smell and a saline taste. Test paper for chemical purposes is prepared with a watery infusion, consisting of one part of powdered litmus to 4 of water. This is applied by means of a brush to white unsized paper, or paper free from alum and other *acid* salts. The sheets, when dried, should be kept in close vessels in the dark.

403. *Cochineal* is a little insect, the *coccus cacti*, which lives on several species of cactus, found in warm climates, and cultivated for this purpose in Central America, and the southern part of Mexico. The dried body of the insect yields to water and alcohol a magnificent red coloring matter, precipitable by alumina and oxide of tin. *Carmine* is a precipitate of this kind. This substance is often adulterated with starch or vermillion, and is sometimes rendered paler by an excess of alumina used in its precipitation. This is detected by ammonia, which dissolves pure carmine, and leaves behind the substances with which it is adulterated.

404. *Madder* is the most permanent and valuable of the red dye stuffs. The plant from which it is obtained is a native of the South of Europe, and is cultivated in France and Holland. From the latter country most of the madder of commerce is procured. The coloring matter, which may be extracted from the root by several different processes, forms yellowish red acicular crystals, easily soluble in alcohol, but sparingly dissolved by boiling water. It resists the action of concentrated sulphuric acid, and may be sublimed without decomposition. A purple or brown, and a yellow coloring matter also exist in madder; the latter is very soluble in water.

405. *Brazil wood, and logwood* give red and purple infusions, which are largely employed in dyeing. The coloring

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402. What is said of litmus?

403. Whence is cochineal obtained? What is carmine?

404. What is said of madder? Whence is it obtained? Mention some of its properties.

principle of logwood has been obtained in crystals. Acids brighten these colors, and alkalies render them purple or blue. Among yellow dyes are *quercitron bark*, *fustic wood*, and *saffron*. These give yellow infusions to water, and furnish more or less permanent colors. The green covering of the walnut, is used to dye brown.

ANIMAL CHEMISTRY.

406. Life controlls all other agencies in animal as well as in vegetable chemistry; these two departments are, however, marked by many striking and characteristic differences, among which are the following:

1. The combinations produced by the principle of life in the animal organization, are *far more complex* than those produced in the vegetable kingdom. Not only the structure of the bodies of animals, but their chemical composition, is far more complex than those of the forms of vegetable life.

2. The great mass of vegetable substances consist of *non-azotized substances*, consequently of substances which contain only three elements; but in the animal body, the *azotized* and the *sulphurized* substances predominate. Water and fat are almost the only substances composed of two or three elements that occur in the animal body; all the others, as flesh, cartilage, blood, hair, nails, &c., are rich in nitrogen, sulphur, and also contain phosphorus.

3. Most animal substances, when viewed under the microscope, exhibit the form of small globules. In the mineral kingdom, the angular (crystaline) form prevails. The vegetable kingdom, holding a middle position between the animal and the mineral, affords examples of both kinds of forms, viz., the globular or spherical, in starch, yeast, &c., the crystaline in sugar, organic acids, bases, &c.

4. The elements of which animal substances are formed, are exactly the same as those which occur in the vegetable kingdom, viz., *oxygen*, *hydrogen*, *carbon*, *nitrogen*; also, *sul-*

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405. What other dye woods are mentioned?

406. What is said of the agency of life in animal chemistry? In what respects are animal organizations more complex than vegetable forms? What is the second difference between animal and vegetable substances? What is the third difference? What have animal and vegetable substances in common to a great extent? What is said of the agency of cellular action in the animal body? How do the changes which occur in the animal body compare with

phur, *phosphorus*, *and chlorine*, and the metallic substances, *lime*, *potassium*, *sodium*, and *iron*.

5. The agency of *cellular action*, (p. 232,) in the animal body, is much more feeble and more limited than in vegetable life. In the vegetable world, by the action of cells, all the substances visible in the plant, are produced out of purely inorganic matter. In an animal, this agency is confined to the modification or change of complex organic principles already existing; principles which owe their origin to plants. A building up, an organizing power, is indeed manifest, but the materials are furnished, as it were, to its hand, in a state requiring an exertion of chemical force infinitely less energetic than that required to produce woody fibres, or sugar from carbonic acid and water. The most intricate and refined changes are produced by vegetable life, changes incomprehensible in their nature, though evident in their effects; they are in the ascending scale, producing organic substances from inorganic. The changes which occur in the animal body, are chiefly in the descending scale, forming compounds less and less complex by changes which we can in most instances understand, and in some imitate, until they at length reach the inorganic condition, and once more become capable of assimilation by plants. A perpetual and unbroken chain of agencies is thus established, the products of the one order of beings becoming the sustenance of the other.

The following table exhibits in a striking light the opposite functions of plants and animals.

The vegetable	The animal
Produces neutral azotized substances,	Consumes neutral azotized substances,
" fatty substances,	" fatty substances,
" sugar, starch, and gum,	" sugar, starch, and gum,
Decomposes carbonic acid,	Produces carbonic acid,
" water,	" water,
" ammoniacal salts,	" ammonical salts,
Disengages oxygen,	Absorbs oxygen,
Is an apparatus of reduction,	Is an apparatus of oxidation,
Is stationary.	Is locomotive.

6. The vital principle produces *a continual equilibrium in the animal frame*. This is also the case in all organic life, but in animal life it is pre-eminently true. Without a constant repair, or renewal of the whole animal system by deposition and organization of matter from the blood, the body would soon waste away. This organization of matter is

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those produced in vegetable substances? What is said of the action of the vital principle in maintaining an equilibrium in the animal frame? What is the difference between the food of animals and that of plants? Whence are the self-regulating, or varies with the demands of the system, so that, though in circumstances always changing, and experiencing within itself continual changes, amounting to many hundred pounds in the course of a year, the animal frame preserves its weight from year to year, very nearly the same in amount. Art is far outdone, and must ever be, for no contrivance of man is destined to a perpetuity beyond the materials of which it is at first constructed.

7. The food of animals consists for the most part of *organized matter*, while that of vegetables is derived from the *inorganic kingdom*. The inorganic constituents of vegetables are derived from the soil, and from the decomposition of other vegetables, which by decay, fermentation, or putrefaction, lose their organic character, and are resolved into their inorganic elements.

8. The food of the two great classes of animals, the graminiverous, or the vegetable feeders, and the carniverous, is composed of essentially the same principles. Vegetable albumen, fibrine, and caseine, the food of the former class, are in composition identical with bodies of the same name extracted from blood and milk, and which are the food of the latter class of animals.

CONSTITUENTS OF THE ANIMAL BODY.

407. *Fibrine*, $C_{400}H_{310}O_{120}N_{50}+PS$. This substance is found in two distinct conditions in the living animal; in the blood, where it is dissolved, perfectly fluid, and in the muscular flesh, of which it forms the characteristic ingredient. In the latter it is solid and insoluble, or coagulated. When a thin slice of muscle is washed in cold water until perfectly white, it is seen to consist of a stringy-looking substance, which is the fibrine itself, traversed in all directions by blood vessels, nerves, and membranous matter. Fibrine is also deposited when the expressed juice of plants, such as beets, turnips, &c., is allowed to stand. This appears in every respect the same with animal fibrine. The latter is usually prepared by beating fresh drawn blood with twigs, and washing the clot which adheres to the twigs with water and ether.

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inorganic constituents of plants derived? In what respects is the food of all classes of animals alike?

407. Write the formula for fibrine. How does this substance occur in the animal body? How may vegetable fibrine be obtained? How does this compare with animal fibrine? How is animal fibrine usually prepared? Mention some of its properties. How is it shown that arterial differs from venous fibrine?

In a fresh state it forms long, white, elastic filaments, which, under the microscope, appear to be composed of small globules arranged in strings; it is quite tasteless, and insoluble in both hot and cold water. By long continued boiling it is partly dissolved. When dried in vacuo, or at a gentle heat, it loses about 80 per cent. of water, shrinks very much in volume, and becomes translucent and horny. When again moistened, it recovers, for the most part, its former bulk.

The fibrine of arterial and venous blood, is not absolutely the same. When the venous fibrine of human blood is triturated in a mortar with 1½ times its weight of water, and ⅛ its weight of nitrate of potash, and the mixture left twenty-four hours or more at a temperature of 100° to 120°, it becomes gelatinous, and exhibits all the properties of a solution of albumen which has been neutralized by acetic acid. It eventually becomes liquid. Arterial fibrine treated in the same way does not become liquid, nor does the fibrine of venous blood when long exposed to the air or to oxygen. The fibrine of muscular flesh resembles that of venous blood.

408. *Albumen*, $C_{400}H_{310}O_{120}N_{50}PS_2$. This formula is the same with that of fibrine, with the exception of S_2 instead of S in fibrine. White of egg, and the clear *serum*, or fluid part of the blood, contain albumen, associated with soda, from which it may be obtained by neutralizing the soda with acetic acid, and by diluting with cold water. The precipitate of albumen thus formed, is soluble in water containing a minute quantity of alkali. By a sufficient heat, albumen coagulates and becomes a white body, wholly insoluble in water. With metallic salts, as corrosive sublimate, it gives insoluble precipitates; hence its use as an antidote for that poison.

After the fibrine is removed from the expressed juice of plants, by the process mentioned above (407.), if the temperature of the juice be raised to 212°, it becomes a second time turbid with *vegetable albumen*. A third principle is obtained after the albumen is separated, by slowly evaporating the solution. This is vegetable *caseine* which appears in a film on the surface.

409. *Caseine*, $C_{400}H_{310}O_{120}N_{50}S$, is found only in milk, where it exists in a state of perfect solution, owing, like al-

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408. Write the formula for albumen. How does this formula differ from that of fibrine? Where is albumen found? How may it be obtained from these substances? Why is it used as an antidote for corrosive sublimate? How may vegetable albumen and vegetable caseine be obtained?

409. Write the formula for caseine. How does this formula differ from that

bumen, its solubility to a small quantity of alkali. Unlike albumen, however, caseine is not coagulated by heat. The addition of a little acid of almost any kind, precipitates caseine from milk, by neutralizing the alkali which held it in solution. An exceedingly small quantity of acid will effect the precipitation when the reaction is aided by a gentle heat.

A solution of caseine may be coagulated by certain animal membranes. On this principle, the manufacture of cheese depends. A piece of the lining membrane of the stomach of an animal, more particularly that of a young animal, as a calf, is cleansed by slight washing in cold water, plunged into a large mass of milk, and the temperature of the whole slowly raised to about 120° or a little higher. At a particular moment the milk undergoes a very complete coagulation. It separates into solid, white, opaque *curd*, and into thin, pale-colored, translucent *whey*. The former consists chiefly of caseine and butter, the latter of water, holding in solution most of the saline compounds of the milk, together with milk sugar, to which it owes its sweetness. The curd is drained, mixed with salt, and sometimes other condiments, and then undergoes various manipulations, the principal object of which is to communicate consistence and form, and to get rid of superfluous moisture. The cheese thus formed, is allowed to remain in a cool situation for several months, and undergoes a particular kind of putrefactive fermentation, upon which its flavor and value depend.

The following table gives the composition of several varieties of cheese, of which No. 1 is skimmed milk cheese. One hundred pounds of cheese contain—

	No. 1.	No. 2.	No. 3.	No. 4.
Water,	43·82,	35·81,	38·58,	38·46.
Caseine,	45·04,	37·96,	25·00,	25·87.
Butter,	5·98,	21·97,	50·11,	31·86.
Ash,	5·18,	4·25,	6·29,	3·81.

From this table it appears that cheese contains from ⅓ to ½ its weight of water, and also, with the exception of skimmed milk cheese, from ⅕ to ½ of butter.

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of fibrine and that of albumen ? Where is this substance found ? Why is caseine dissolved in milk ? Is caseine coagulated by heat ? How may this substance be precipitated from milk ? Upon what does the manufacture of cheese depend ? Into what two portions is the milk separated ? Of what does caseine consist ?—whey ? How is cheese prepared from the curd ? How much water does cheese contain ? How much butter ? What kind of cheese contains the most caseine ? What is said of skimmed milk cheese ? What four

Skimmed milk cheese, on the other hand, contains the largest amount of caseine, amounting to nearly half of its weight. This renders this kind of cheese very nutritious, while it is not as rich as the other kinds, and, therefore, might well form a principal article of diet.

Fibrine, albumen, and caseine, are very nearly alike in their composition, as appears from their formulæ:

$$C_{400}H_{310}O_{120}N_{50}PS.$$
$$C_{400}H_{310}O_{120}N_{50}PS_2.$$
$$C_{400}H_{310}O_{120}N_{50}+S.$$

In these formulæ, C, H, O, N, are the same, and in the same proportions. From this it is supposed that these elements form a substance to which the name *proteine* has been given, although this has never been *entirely* isolated. With proteine, phosphorus and sulphur are supposed to be combined, forming fibrine, albumen, or caseine, according to the proportions in which they unite with proteine. Hence, these three substances are called the *proteine group*.

410. *Gelatine*, $C_{13}H_{10}N_2O_5$, is obtained from animal membranes, skin, tendons, and bones. These dissolve in water, at a high temperature, more or less completely, but with very different degrees of facility, giving solutions which, on cooling, acquire a soft, tendinous consistence. This substance is termed gelatine. It does not pre-exist in the animal system, but is generated from the membranous tissue by the action of hot water. The jelly of calves' feet, and common size and glue, are familiar examples of gelatine in different conditions of purity. Isinglass, the dried swimming bladder of the sturgeon, dissolves in water merely warm, and yields a beautifully pure gelatine. In this state it is white and opalescent, or translucent, quite insipid and inodorus, insoluble in cold water, but readily dissolved on a slight elevation of temperature. Cut into slices and exposed to a current of dry air, it shrinks very much in volume, and becomes a transparent, glassy, brittle mass, which is soluble in warm water, but insoluble in alcohol or ether. Long continued boiling gradually alters it, and the solution loses the power of forming jelly on cooling. One part of dry gelatine dissolved in 100 parts of water, solidifies on cooling.

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elements are in the formulæ of caseine, albumen, and fibrine, in the same proportions? What is inferred from this fact? What are these three bodies called?

410. Write the formula for gelatine. Whence is gelatine obtained? How is it prepared? In what substances is gelatine found in a state of great purity?

An aqueous solution of gelatine is precipitated by alcohol, which withdraws the water. Corrosive sublimate in excess gives a white flocculent precipitate, and the same is produced by the nitrate of the suboxide and the protoxide of mercury. With tannic acid, or infusion of galls, it gives a copious, white, curdy precipitate, which coheres on stirring to an elastic mass quite insoluble in water, and incapable of putrefaction. Chlorine passed into a solution of gelatine, condenses a dense, white precipitate of chloride of gelatine, which envelops each gas bubble, and ultimately forms a tough, elastic, pearly mass, somewhat resembling fibrine. Boiling with strong alkalies converts gelatine into *gelatine sugar*, a sweet, crystalizable principle, containing $C_4H_5NO_4$.

Common glue is prepared from refuse skin or bones, either by extraction with hot water, or by the pressure of steam. The best glue is prepared by the latter process. The concentrated hot solution is then allowed to settle, and the thin liquor yields on cooling, a stiff jelly, which is cut by wires into thin cakes, and placed to dry upon packthread nettings, which give it the common grooved appearance. The horns of the hart produce gelatine of the first quality. These are reduced to the state of shavings, that the gelatine may be more easily extracted. Jellies for invalids are often prepared from these shavings. The adhesive power of glue is much increased by adding to it white lead or borax (about 1 oz. or 1½ oz. to 1 lb. of glue.)

If a solution of gelatine, albumen, fibrine, caseine, or probably any of the more complex azotized, animal principles, be mixed with a solution of sulphate of copper, and a large excess of caustic potash be added, the greenish precipitate first formed is redissolved into a purple solution of indescribable magnificence, and great intensity.

Gelatine is largely employed as an article of food, in soups, &c. Great quantities of size and glue are consumed in the useful arts.

411. *The blood, respiration.* The blood is the general circulating fluid of the animal body, the source of all nutriment and growth, the general matter from which all secretions, however much they may differ in properties and composition, are derived. Food or nourishment can only be made available by being first converted into blood. It serves also

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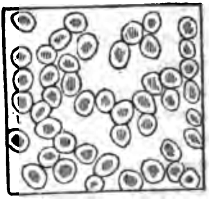
Mention some of its properties. Write the formula for gelatine sugar. How is this substance prepared? How is common glue produced? Mention some of the uses of gelatine.

411. Mention some of the purposes which are served by the blood. Explain

the scarcely less important office of removing from the body principles which are no longer required.

While circulating in the vessels, blood consists of a nearly colorless and transparent liquid, in which float myriads of minute, vesicular bodies, or corpuscles, of which by far the greater number are of a bright red color, (Fig. 103.) These are so small as to be individually quite invisible to the naked eye, and therefore give the blood the appearance of a homogeneous red fluid. Besides the red corpuscles, there are always present a few colorless particles having irregular forms, and differing in other respects from the red corpuscles.

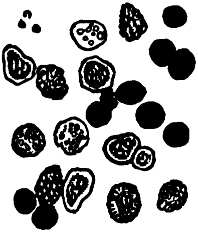
Fig. 103.



Blood corpuscles magnified 400 diameters.

These bodies are found to present different appearances in the blood of different animals. In the mammifers they are round, red or yellowish discs; in birds, lizards, frogs, and fish, they are elliptical. In magnitude, they differ with the *genus* and *order*, although quite constant in members of the same species. The red corpuscles of the human blood vary from $\frac{1}{5000}$ to $\frac{1}{2000}$ of an inch in diameter, while in the frog the longer diameter of the ellipse measures at least four times as much. In some of the lower order of animals the blood is entirely devoid of redness, and nearly colorless. This is called *white blood.* With white blooded animals the muscles are also white, as with fishes, frogs, reptiles, &c.

Fig. 104.



White corpuscles of the blood magnified 400 diameters.

The temperature of the blood in all vertebrated animals, is above that of the medium in which they live. In the mammalia this is very apparent, and in birds still more so. The heat of the blood is dependent upon respiration, and is proportioned to its activity. In man it does not vary much from 98°, even under great vicissitudes of climate, provided the system be in a healthy state. In birds it is sometimes as high as 190°. This blood consists of two kinds, which differ considerably, viz., that contained in the *left side of the heart and in the arteries generally*, and that

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figs. 103 and 104. What is said of the temperature of the blood? Of what kinds is blood composed? What is said of the arterial blood?—of venous blood? In contained in *the right side and in the veins.* The arterial blood is bright red; the venous blood is dark claret-colored, sometimes approaching to black. The blood streams out of the left side of the heart through the arteries into all parts of the body, from which it returns dark colored through the veins to the right side of the heart. Before it recommences its circulation, it is impelled through the lungs, in which it comes into contact with the air. This enters through the cellular membrane of the lungs by *endosmose* (189.) and uniting with the carbon of the venous blood, (forming carbonic acid,) escapes by *exosmose* without the cells of the lungs, whence it is exhaled to the external air. By this process the excess of carbon being removed from the dark venous blood, it is converted into light arterial blood. The formation of carbonic acid within the lungs is the same as that in the combustion of fires, and is attended by many of the same effects. When wood is burned, the oxygen of the air unites with the carbon of the wood, and carbonic acid is formed; heat is at the same time given out. In the same manner the oxygen of the air unites with the carbon of the blood, *chiefly* in the lungs, and while carbonic acid is formed heat is also evolved. Wood supplies the fire and continues its combustion; food supplies the wants of the animal body and continues the vital heat.

In its ordinary state, the blood has a density varying 1·053 to 1·057. It feels slimsy, and has a decidedly alkaline reaction. It has a saline and disagreeable taste, and, when quite fresh, a peculiar odor, or *halitus*, which almost immediately disappears. An odor may, however, afterwards be developed by adding sulphuric acid, and this odor is by some considered characteristic of the animal from which the blood was obtained.

One of the most remarkable peculiarities of the blood, is its spontaneous coagulation when separated from the body. The fibrine of the blood is held in a state of solution, while circulating in the vessels, but no sooner is the blood removed from the system, than it begins to separate in the solid state, after which it becomes quite insoluble in water. If this coagulum be placed upon bibulous paper, and drained as much as possible from the fluid portion, and then put into water, the *coloring matter* dissolves, forming a magnificent crimson solution. This is called *hematozine.* It contains albumen and coagulates by heat, and by addition of alcohol, but cannot be separated from the albumen. Hematozine differs from the other animal principles, in containing as an essential ingredient, *oxide of iron.* A solution, rich in oxide of iron, may be obtained from the dried clot of blood by calcining it in a crucible, and digesting with dilute hydrochloric acid. The healing of wounds is produced by the coagulation of the fibrine of blood, and furnishes one of the most striking proofs of design in the construction of the human frame. When an incision, or laceration of the body happens, the blood issues from the divided vessels, fills up the wound, and then coagulates, unless a very large vessel should be opened, and the blood flow too rapidly and escape. The clot remains while the serum evaporates. *Organization* then takes place in the fibrine; that is, new blood vessels are formed in it, connected with the adjacent old ones; new nerves are also produced through it, and it soon becomes a living mass. Rest and quiet are all that nature requires to complete the process, and the simplest dressing of the wound is, therefore, all that is required.

The composition of human blood varies continually in a greater or less degree. It cannot, therefore, be determined, except for the *individual,* and the *time.* The slightest cause, as for instance, drinking water freely, will effect an entire change in the analysis of the blood of individuals. The following table, will, however, give a general idea of the constitution of the blood:

In 1000 parts of blood were contained in two analyses:

Water,	780·15,	785·58.
Fibrine,	2·10,	3·57.
Albumen,	65·09,	69·41.
Crystalizable fat,	2·43,	4·30.
Fluid fat,	1·31,	2·27.
Extractive matter,	1·79,	1·92.
Albumen in combination with soda,	1·26,	2·01.
Carb. sodium and potassium; Carbonates, phosphates, and sulphates of potash and soda,	8.37,	7·30.
Carbonates of lime and magnesia; phosphates of lime, magnesia, and iron, peroxide of iron,	2·10,	1·42.
Loss, - - - - - - - -	2·40,	2·59.
	1,000·00,	1,000·00.

The presence of saline matter and albumen in the blood, prevents the solution of the red corpuscles. These are very

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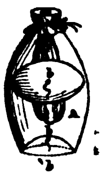
the other animal principles? How is the healing of wounds produced by the coagulation of blood? Why are not the red corpuscles dissolved in the blood?

easily soluble in water, and the limit of dilution within which they can remain uninjured, is nearly reached in the blood, for when water is added, they are immediately attacked.

412. *The lungs* are made up of an immense number of cells connected with the windpipe. In the act of respiration, they are perfectly passive, the air being introduced and expelled alternately by the contraction of the muscles of the chest. The manner in which this is done, may be understood from Fig. 105. Let the glass globe, A, represent the *capacity* of the chest; *b*, *b*, are sheets of gum-elastic stretched over openings in the globe. B is a bladder introduced into the top of the globe, and tied over the neck in such a manner, that the air can enter within the bladder, but not within the globe. If now the sheets of gum-elastic *b*, *b*, be drawn out by the strings attached to the center of these sheets, the capacity of the globe will be enlarged, and, consequently, the air within will be rarefied. The external air, therefore, rushes into the bladder through the top, and dilates it exactly in proportion as *b*, *b*, are drawn out. If *b*, *b*, are now allowed to contract and return to their former position, the bladder will also contract and become flaccid as at first. In a similar manner, when the cavity of the chest is enlarged, the air rushes into the lungs, which are suspended in the chest like the bladder in the glass globe, and when this cavity is diminished, the air is forced out. The capacity of the chest is enlarged, both upwards and downwards; upwards by muscles, the contraction of which draws the lower ribs upwards and *outwards;* downwards by the contraction of the diaphragm, which covers the bottom of the chest.

Fig. 105.



The number of respirations average about 17 each minute, and at each respiration, about 17 cubic inches of air are introduced. By a forced effort, 50 or 60 cubic inches may be expelled. About seven tons of blood are daily exposed to 226 cubic feet of air. Inhabitants of very cold countries maintain the temperature of the body, by consuming enormous quantities of food of a fatty nature, the carbon and hydrogen of which are chiefly employed in the production of animal heat. These people live by hunting, an occupation that requires great muscular exertion, and consequently quick-

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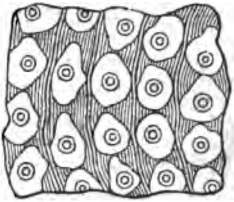
412. What is said of the lungs? Explain Fig. 105. How do inhabitants of very cold countries maintain the temperature of their bodies?

ens and deepens the breathing, while from the increased density of the air of those regions, a greater weight of oxygen is taken into the lungs, and absorbed into the blood at each inspiration. In this manner, the temperature of the body is kept up, notwithstanding the piercing cold.

413. *The skin* is an elastic substance, covering the whole body. It consists of a thick tissue of cells between which are small openings (pores). Fig. 106, represents a piece of human skin, as magnified by the microscope. Through these pores, a substance, partly oily and partly watery, is separated, together with some carbonic acid. There is a slight difference in the composition of the finely organized and highly elastic membrane which forms the coat of the arteries, and the coarse epidermis of the foot, as will be seen from the following analysis:

Fig. 106.



	Artery coat,	Epidermis.
Carbon,	53·75,	51·04.
Hydrogen,	7·08,	6·80.
Nitrogen,	15·36,	17·23.
Oxygen,	23·81,	24·93.
	100·00,	100·00.

A little sulphur was found in the epidermis. Hair, horn, nails, wool, and feathers, have a similar composition. They all dissolve in caustic potash with disengagement of ammonia, and the solution when mixed with acid, deposits a kind of proteine (p. 293) common to the whole.

In an experiment tried on a healthy individual, it was found that 14 oz. of carbon were given off in the state of carbonic acid in 24 hours, from the lungs and the skin. During the same time a horse consumed in respiration 77 ounces, and a cow 70 ounces.

414. *Milk*, when examined by a microscope of even moderate power, appears to consist of a perfectly transparent

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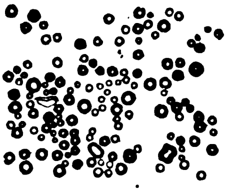
413. Of what does skin consist? Explain Fig. 106. What is the office of the pores?

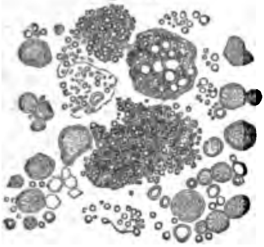
414. Of what does milk consist? Explain Figs. 107 and 108. What is cream? How is butter produced? How may butter be preserved a great length of

Fig. 107.



fluid, in which float numbers of transparent globules, which consist of fat (Fig. 107.) The size of these globules varies from a mere point to about $\frac{1}{2000}$ of an inch in diameter, the average size being rather more than $\frac{1}{4000}$ of an inch. The milk which is obtained during the first few days of lactation, is always much richer than ordinary milk. In this we find, in addition to the common milk globules, numerous granular corpuscles (Fig. 108.) of a pale, yellowish color, and considerably larger than the others, their diameter varying from $\frac{1}{2000}$ to $\frac{1}{800}$ of an inch.

Fig. 108.



When suffered to remain at rest for some hours, at the ordinary temperature of the air, a large proportion of fat globules collect at the surface in a layer of cream. If this be now removed and exposed for sometime to strong agitation, the membranes of the oil globules are torn, they coalesce into a mass, and the remaining watery liquid is expelled from between them. The butter so produced must be thoroughly washed with water, to remove as far as possible the last traces of caseine, which readily putrifies, and would in that case spoil the butter. A little salt is usually added. The butter thus prepared is not entirely free from butter milk, and, therefore, cannot be preserved a great length of time, without being *clarified* by fusion. The watery part then subsides, and carries with it the residue of the azotized matter. This process, unfortunately, impairs the flavor of the butter, and is not, therefore, generally adopted. The proportion of margarine and oleine in butter, on which depends its consistence, varies with the season, or rather with the kind of food. In summer, the oily portion is more considerable than in winter. In a fresh state, when taken from a healthy animal, milk is always feebly alkaline. When left to itself, it soon becomes acid, and is found to contain *lactic acid*, which cannot be discovered in the fresh condition. The al-

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time? Has fresh milk alkaline or acid properties? To what is the alkaline character of fresh milk owing? Why is phosphate of lime dissolved in milk? What acid is produced in milk on standing? What is said of the density of milk?

kalinity is due to the soda which holds the caseine in solution. In this soluble form, caseine possesses the power of taking up and retaining a considerable quantity of phosphate of lime. The density of milk varies exceedingly, and its quality usually bears an inverse ratio to its quantity. By feeding on certain kinds of food, the quantity is often increased at the expense of the quality. An analysis of cow-milk gave the following result:

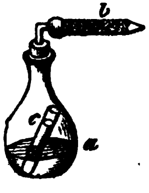
One thousand parts of milk contained

Water,	873·00.	Phos. magnesia,	0·42.
Butter,	30·00.	" iron,	0·07.
Caseine,	48·20.	Chloride of potassium,	1·44.
Milk-sugar,	43·90.	" sodium,	0·24.
Phosp. lime,	2·31.	Soda,	0·42.

415. *The production of fat* is increased by a state of rest, a warm situation, and an abundant supply of food. Every part of the body is wasting away, but this waste takes place much more rapidly by exposure to cold, or with active exercise. The fat of an animal is a provision of nature for the maintenance of life during a certain period of privation. This may be produced by the vital energies from food that contains no fat; thus bees will produce wax, though fed upon pure sugar, and animals will grow fat on food that contains no nitrogen, although this is an essential constituent of fat. Still the assimilation of fat takes place much more readily from food in which it is already contained, and hence this deposition, and the production of butter from the milk of an animal, bear a certain relation to the amount of oleaginous matters found in its food. For this reason, Indian corn, which contains from 8 to 12 per cent. of oil, furnishes one of the most valuable articles for feeding and fattening cattle. *Oil cake*, or the residue of linseed oil factories, produces a still more striking effect in fattening cattle.

416. *Bones* consist of an animal and an earthy matter (phosphate of lime, bone earth.) Bones also contain from 6 to 7 per cent. of carbonate of lime. The amount of this substance in bones, is determined by the arrangement represented in Fig. 109. A small portion of the pulverized bone is put into the flask, *a*. This flask contains a little water, and a small tube, *c*, holding hydrochloric acid. A chloride of calcium tube, *b*, is attached to the cork. The whole apparatus is now weighed,

Fig. 109.



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415. What circumstances tend to increase the production of fat? What is the object of fat?

after which, the acid is allowed to flow gradually out of the tube, *c*, by inclining the flask. The dilute acid thus formed in *a* acts upon the pulverized bone and expels its carbonic acid. This passes off through the chloride of calcium tube, *b*, by which it is deprived of its moisture, and thus nothing but carbonic acid escapes from the apparatus. The amount of this gas is, therefore, what is lost, which may be determined by weighing the apparatus again, and comparing the second weight with the first. From the amount of carbonic acid thus determined, that of the carbonate of lime may be ascertained, for 50 parts of carbonate of lime contain 22 parts of carbonic acid, and the weight obtained must therefore be increased in the proportion of 50 to 22.

The following table shows the composition of the bones of an adult, compared with those of a child:

	Inorganic matter.		*Organic matter.*	
	Adult.	*Child.*	*Adult.*	*Child.*
Femur,	62·49	57·51.	37·51	42·49.
Humerus,	63·02	58·08.	36·98	41·92.
Radius,	60·51	56·50.	39·49	43·50.
Os temporum,	63·50	55·90.	36·50	44·10.
Costa,	57·49	53·75.	42·51	46·25.

From this table it appears that the bones of the adult are in every instance richer in earthy salts than those of a child. During the earliest periods of life, they consist almost entirely of gelatinous membranes, having the form of the bones, but of a loose, spongy texture. The cells or cavities of this texture are afterwards filled with phosphate of lime, and by the gradual acquisition of this salt, the bones acquire hardness and durability. A portion of the phosphate, after the bones of the infant have been sufficiently expanded and solidified, is deposited in the teeth, which consist at first only of a gelatinous membrane, or case, fitted for the reception of this salt. After acquiring hardness within the gum, the new formed tooth protrudes from it.

In quadrupeds, the phosphate of lime is deposited likewise in their horns and the hair or wool with which they are generally clothed. In birds it serves also to harden the beaks, and the quills of their feathers. When animals have arrived at a state of maturity, and their bones have acquired sufficient solidity, the phosphate of lime which is taken with the food is seldom assimilated, excepting when the female nourishes

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416. Of what do bones consist? Explain Fig. 109. In what respect does the composition of the bones of a child differ from that of the bones of an adult?

her young with milk; it is then assimilated in the milk for them, to strengthen and complete their bones.

417. *Relations of chemistry to common life.* In the brief survey which we have now taken of this most extensive science, we have found every part intimately connected with life. In inorganic chemistry, we have been led to the composition, and, in a degree, to the *forms* of vegetable and animal structures; we have followed the principle of life in its organization of the animated world around us, and of our own frames. In organic chemistry we have become acquainted with the nature and properties of bodies, which, either in their simple state or in combination with other bodies, we are constantly meeting with, and employing in the various processes of art, of agriculture, of domestic economy, or in medicine. While such is the wide range of this science, there is none that so thoroughly investigates the bodies which are the objects of its study. The atoms of these bodies are its appropriate study, and all its investigations are founded, not upon the laws which control masses, but upon those which govern the ultimate particles of bodies. Hence, its knowledge is complete; so far as explored, the subjects of its study are thoroughly known.

In this thorough investigation of nature, we find no fault to mar the beauty or perfection of her works. The smallest atoms are obedient to laws of perfect wisdom, and every compound which these atoms form, is perfect in its construction and in the properties by which it is related to other bodies.

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417. What is said of the relations of chemistry to common life? How does this subject illustrate the wisdom and goodness of the Creator?

EXPERIMENTS.

(1.) *Freezing mixtures;* snow 4 drams, chloride of calcium (pulverized) 5 drams,—this mixture freezes mercury, and the thermometer sinks from 32°+to —40°;—snow 2 drams, chloride of calcium 3 drams,—this mixture freezes nitric acid, and the thermometer sinks from 15°+to —8°; snow 8 drams, sulphuric acid (diluted,) 10 drams,—freezes almost every known liquid; alcohol, however, is said to require a freezing mixture of —110°. When the thermometer is reduced by the last mixture to—68°, it may be reduced by this to —91°.

(2.) *Bengal lights;* nitre 28 oz., sulphur 12 oz., realgar or orpiment (313.) 2 1-2 oz.; or nitre 6 oz., sulphur 2 oz., orpiment 1 oz.; or nitre 6 oz., sulphur 2 oz., sulphuret of antimony 1 or 2 oz. *Indian white fire;* dry saltpetre 24 parts, dry sulphur 7, fine dry charcoal 1; or realgar 2 parts instead of the charcoal. The whole should be intimately mixed and cautiously dried near the fire or over a stove. *Chinese fire;* meal powder (crushed powder) 1lb., sulphur 2 oz., sulphuret of iron 2 oz., or meal powder 1 lb., sulphuret of iron 4 oz. *Port fire,* nitre 4 oz., sulphur 2 oz., gunpowder 1 oz. *Red and green fire* are very difficult to make, but they may be purchased cheaply at Chilton's, in New York. The volume of flame in these fire works may be greatly augmented by the addition of a little Canada Balsam.

(3.) *Sulphuric acid* 1 oz., water 1 oz. This mixture will boil water in a glass tube. Concentrated sulph. acid dropped into water causes a hissing sound like red hot iron.—Rub together sulphur and potash in equal parts; they unite with heat, and form sulphuret of potash.—Add 1 oz. of hydrochloric acid to 1 oz. of ammonia, great heat will be produced by the mixture. Most intense heat is produced when 1-2 oz. of hydrofluoric acid is added to an ounce of water. This acid should be poured from a leaden bottle attached to a stick, four or five feet long, and the cup containing the water, should stand on the hearth.—Add water to quicklime (p. 172.) Greater heat is produced by adding sulphuric acid to lime.—Mix 1-2 oz. of strong sulphuric acid with 1 oz. of strong nitric acid, and pour the mixture into oil of turpentine. The turpentine will burst into a flame.

(4.) *Decompositions by Galvanism.* Color sulphate of potash solution with litmus. Pour this solution into a large glass bowl or vase, and fill two large tubes with the same solution. Invert the tubes in the bowl, and underneath introduce the electrode,* rising a considerable height within the tubes. A change of color will soon appear. The solution in the tube containing the positive electrode, will become red, that in the other tube, will become deep blue. The electrodes in this experiment should terminate in long strips of platinum foil. To vary the experiment, take a single narrow glass jar, or very wide tube, and within this insert both of the electrodes. The part of the solution towards the positive electrode will become red, while that towards the negative electrode will be deep blue. This result is produced by the decomposition of the sulphate of potash which contains an acid (sulphuric), united to an alkali (potash.) When decomposed the acid goes to the positive electrode and colors the solution of litmus around that electrode red, while the alkali goes to the negative electrode, and that portion of the solution therefore becomes blue. To vary this experiment still farther, use cabbage liquor instead of litmus solution with the sulphate of potash; also connect the two vessels containing the solution with lamp-wick or fine asbestos, and place one electrode in one vessel, and the other electrode in the other vessel. The different colors in this case will appear in the different vessels, for the acid and alkali of the solution will pass through the asbestos, the first to the vessel containing the positive electrode, and the second to the vessel containing the negative electrode.—Add hydochloric acid to a solution of sulphate of indigo. In this solution place the electrodes while the battery is in action. The hydrochloric acid will be decomposed in the solution. Its chlorine set free will *bleach* (138.) the sulphate of indigo.—Add iodate of potassa to a solution of starch. Place the electrode in the solution, and the iodate of potassa will be decomposed. Its iodine set free will *color the starch blue* (141.) If hydrochloric acid be now added, and the galvanic action continued, the acid will be decomposed, and the chlorine set free will *bleach* the blue iodide of starch in the solution.—Prepare a paper by covering it with a solution of starch, to which iodate of potassa has been added. While the paper is still moist, place the point of one of the electrodes upon it and draw the point of the other over it. This last point will make a blue line wherever it crosses the paper, for, in this line, the iodate of potassa will be decomposed by the galvanic current, and the free iodine will color the starch with which it is in contact. In this manner, blue letters and blue writing may be formed with the metallic point of the electrode. A solution of litmus reddened by hydrochloric acid may be *bleached*, by placing the electrodes in the solution. Were it not for the bleaching property of chlorine, the decomposition of the hydrochloric acid would restore the litmus solution to its original blue color.

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* Greek *electron* and *odos* (the path of the electricity,) applied to the termination of the wires, or the poles and the wire near the pole.

Electrotype decompositions; sulphate of copper, with the deposition of the metal upon any *bright* metallic surface, also chloride of manganese, nitrate of silver, acetate of lead, muriate of tin. Most other salts of these metals will act equally well. A strong solution of caustic potash may be decomposed, and the *metal* potassium (203.) precipitated. For this purpose, pour a thin stratum of mercury into a small glass vessel, having a flat bottom, and add a strong solution of caustic potash above the mercury. Connect an iron wire from the negative pole of the battery with the mercury, and a platinum wire from the positive pole with the potash solution. The potash will be rapidly decomposed, and the precipitated metal will unite with the mercury, forming an amalgam. The amalgam thus formed has the property of dissolving all the other metals.—If a concentrated solution of sal ammoniac be used instead of the caustic potash, an amalgam of mercury and *ammonium* is formed. (There *should be* a reference to this experiment from art. 221.) In forming this amalgam the mercury expands greatly in volume.—The two last experiments may be performed more easily by placing a piece of moistened caustic potash, or sal ammoniac, on a platinum plate which is connected with the negative pole of the battery. Upon the potash, or sal ammoniac, is placed a globule of mercury. When the circuit is completed the amalgam is rapidly formed.

(5.) Few experiments can be performed in electro-magnetism without a battery of considerable power. Among those more easily performed are the following. A wire is rendered magnetic by the galvanic current. Connect the poles of the battery by a wire and it will support iron filings, &c.—If the current passes from north to south *over* a magnetic needle, this will turn at right angles to the wire, and point east and west. The north pole in this case always points east.—If the needle is placed *below* the wire while the current is passing from north to south, the north pole will move towards the west.—By reversing the direction of the *galvanic current* the positions of the needle will be reversed.—These experiments may be still farther varied by passing the galvanic current vertically *either* upwards or downwards.—By making and breaking the contact of the wire with one pole of the battery, and, consequently, making and breaking the galvanic circuit while the needle is near the wire, it may be made to oscillate, and, if the current be sufficiently strong, to revolve the entire circuit. —(*Olmsted's Natural Philosophy*, p. 306.)

(6.) Into melted rosin one part put three parts of lard; the two will unite and form a compound that is more fluid than either of the constituents. Other examples of affinity between bodies of a different nature are salt and snow, snow and sulphuric acid, the metals and the acids.

(7.) Hence similar bodies, as the acids, expel each other to unite with the bases (see note, p. 95,) which are entirely opposite in properties to acids. Hydrocyanic acid is expelled from its combination with baryta by carbonic, carbonic by nitrous, nitrous by sulphurous, sulphurous by boracic, boracic by acetic, and so on in the following order, benzoic, citric, arsenic, tartaric, hydrochloric, nitric, phosphoric, oxalic, sulphuric, which expels all the others from their combinations with baryta. For all other bases a similar succession of affinities by the acids exists, while but few of the bases unite with each other.

(8.) To 1-2 oz. sulphate of soda add 1-2 oz. nitrate of ammonia; no action will take place till they are rubbed together in a mortar, when they combine and the compound is fluid. To 1-2 oz. sulphate of soda add 1-2 ounce sulphate of zinc and 1-2 oz. acetate of lead. The same effect will take place as in the last mixture when these are rubbed together. Solution produces chemical action for a similar reason. Soda powders remain weeks without action unless water be added. Fusion has, in many cases, the same effect. Ice and soda will not act on each other. Silica or sand and soda will not act. But melt the ice or the silica, and the soda will dissolve in the fused mass. Potash and sulphur will not unite until melted together, but after this, the fused mass will dissolve in water without separation, while, before fusion, the potash would dissolve, and the sulphur remain undissolved. The potash and sulphur may also be united by rubbing together in a mortar (Expt. 3.)

(9.) As ammonia and cyanogen are each composed of two elements, their salts contain four elements, as the sulphate of ammonia, which contains sulphur, oxygen, and ammonia (nitrogen and hydrogen), and the cyanate of potash, which is composed of potash, oxygen, and cyanogen (carbon and nitrogen). In the *double salts* (253, and Expt. 56.) the number of constituents is often more than four. A third compound will sometimes increase the affinity of two others, to which it may be added. Thus water will dissolve more quicklime when sugar is added than it will without the sugar.

(10.) The compound of gold and lead is exceedingly brittle, though these metals are malleable, and the first the most malleable of all the metals (315.) Tin and iron form a very brittle alloy, though these metals, separately, are both malleable and ductile. So platinum and lead, two soft metals (when pure), form an exceedingly hard compound. All the compounds of platinum with the soft metals are quite hard. The least alloy of platinum produces this effect; hence, the hardness of ordinary platinum.—Pour a colorless solution of ammonia upon white calomel, the color is changed to a dense black.—Almost all the salts (p. 92.) of the metals are entirely different from the metals, both in their appearance and properties. Sulphate of copper, chromate of potash, the salts of mercury and iron, are examples.

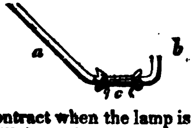
(11.) Iron takes away acid from copper; hence, when a polished knife blade is plunged into a solution of a copper salt, the iron is dissolved, and metallic copper precipitated, which soon covers the knife with a coating of copper. Water takes alcohol from a solution of camphor; therefore, when water is added to this solution, the camphor is precipitated.

Drop a little aqua ammonia into a solution of sulphate of iron. The sulphuric acid of the sulphate of iron will leave the metal to unite with the ammonia. Sulphate of ammonia will be formed, and oxide of iron be precipitated.

(12.) Nitrogen and oxygen in one proportion form *nitrous oxide*. When the oxygen is doubled, they form *nitric oxide*, which is the next compound above nitrous oxide. The next compound, *hyponitrous acid*, contains three proportions of oxygen. Four proportions of oxygen with one of nitrogen, form *nitrous acid*, and five proportions *nitric acid*.

(13.) Fig. 110 represents the best method of preparing this tube. It consists of two parts, *a*, and *b*, united by the india-rubber connector, *c*. This tube may be preserved and used for other gases. The *flexible end*, *b*, will be found very convenient.

Fig. 110.



(14.) What remains in the flask after cooling (this should be gradual) may be dissolved out with water. *The tube, b, should not be left in the water after the gas has ceased coming over*, as the gas within the flask will contract when the lamp is withdrawn, and sometimes before, and this contraction will draw the water up the tube, *b*, into the flask, and produce an explosion.

(15.) *Two fine wires* should be prepared, or two watch-springs. One of the wires or watch-springs should be made into a coil, by taking out the temper and winding it around a ruler, or a glass tube. The coil should be about a half an inch in diameter. The other wire, or watch-spring, should be left straight. The match on the end should be made with considerable care, to insure success and the best effect. It may be made by winding around the end of the wire about six inches of coarse cotton thread, so as to form a little ball. This ball is then dipped into sulphur. Before introducing the wire into the jar of oxygen, as much of the sulphur should be allowed to burn off as possible. This will heat the end of the wire to the requisite temperature, and the waste of oxygen in the consumption of a large amount of sulphur will be avoided.

The following experiments may be tried, to illustrate some of the most important properties of oxygen.—1. Effect on a candle introduced into a jar of oxygen. 2. If the candle has a large wick (as that of a tallow candle), *which remains ignited after being blown out*, it may be relighted in oxygen, and this experiment may be repeated a great number of times with a small jar of oxygen. 4. Burn phosphorus in oxygen—a piece about the size of a pea, in the *deflagrating spoon* (see "chemical apparatus");—do. cotton or *cotton seed*. 5. Show sp. gr. of oxygen, by pouring it out on an extinguished taper or lamp lighter (see "chemical processes"), which may be relighted in this manner. 6. Burn caoutchouc in oxygen—on the end of a copper wire, or in the deflagrating spoon;—do. camphor, sulphur, charcoal (that of light pine wood, or thoroughly charred bark), potassium, red fire (Expt. 2.), in the deflagrating spoon; boracic acid, nitrate of copper mixed with a small quantity of alcohol to inflame it, phosphate or any salt of soda in the same way, nitrate of strontia with alcohol, chloride of lime do., several of the oils, as olive and linseed oils, on cotton attached to a copper wire.

An india-rubber bag may be used to produce a jet of oxygen gas, and by this jet, a variety of beautiful experiments may be performed. It may be used with or without the flame of a spirit lamp, according to the experiment to be performed. When the object is supported on charcoal, a lamp lighter is often preferable to a spirit lamp to commence the combustion, after which it is continued by the charcoal and the body experimented upon. To use this jet, in a small cavity made in the charcoal support (by boring with a large screw-driver or small chisel) introduce the following substances;—nitrate of strontia, nitrate of copper, boracic acid, amber, alum, sulphuret of lead (which is first reduced, and the metallic lead afterwards burns), acetate of zinc, metallic zinc, metallic copper, sulphuret of iron; watch-springs broken up fine and introduced into a deep cavity of the charcoal, and covered with a little lamp black (they are first heated red hot, and then fly off in a shower of brilliant sparks), iron filings prepared in the same way as the watch-springs, carbonate of soda, antimony or one of its salts, oxides of silver and gold (which are reduced to *fulguration*, 211.)

The agency of oxygen in producing colors may be shown by a variety of experiments:—Damp faded silk, placed in a dry phial of oxygen gas, imbibes the gas, and in a few days is restored to its original brilliancy. This effect is, however, sometimes destroyed by the presence of certain mordants [251.] A solution of protoxide (protosulphate) of iron is at first light-yellow, but by agitation absorbs oxygen from the air and becomes reddish-brown. Fluorspar, and most of the gems, owe their colors to the oxygen with which they are combined. Almost all the colors produced in the arts are manufactured from metallic oxides, and not only the intensity of the color, but also the *kind* depends, in a great measure, upon the degree of oxidation of the metallic base. In this way, from bodies which, with few exceptions, possess little beauty of color, the most beautiful and brilliant colors are obtained.—Light, by deoxidizing substances, causes their colors to fade, although in other cases it darkens substances by producing decomposition.

(16.) The action of oxygen in producing acids and alkalies, may be beautifully shown in the following manner:—Into *two* glass basins or vases, pour a solution of litmus, and upon a stand in one of the vases ignite a little sulphur. Over the burning sulphur, invert a jar (compare Fig. 37.) The fumes of the burning sulphur within the jar will form sulphurous acid, and this will be absorbed by the litmus solution beneath, the color of which will change to red. Into the *other* glass vase, place upon a stand a pellicle of sodium or potassium; set this on fire, and invert over it a jar, as in the preceding case. The combustion of the sodium will form soda, which being absorbed by the litmus solution, will color it brown or reddish brown. In the first case, therefore, an acid was formed by the union of sulphur with oxygen, and in the second case, an alkali by the union of sodium with oxygen. The experiment may be varied by using cabbage liquor instead of litmus solution. That oxygen itself is neither acid nor alkaline (although many of the gases are, 147, 156, 158, 160, 161, 162.), may be proved by suspending a piece of litmus paper from the stopper of a jar, and then filling the jar with oxygen. Blue litmus will not be colored red, and reddened litmus will not be tinged blue.

(17.) The air within the jar at first expands by the heat; it must, therefore, have a vent in which it can escape from beneath in such a manner as not to overturn the jar. This may be accomplished, by slightly elevating one side by placing a small support, as a piece of stick, under that side. A better method, where it can be adopted, is to use a *stoppered jar* (see "chemical apparatus"), and to the opening attach a bladder. Press all the air out of the bladder before inverting the jar over the burning phosphorus. The air in this case will find sufficient room for expansion within the bladder, and none need escape from beneath.

(18.) A taper which has been extinguished in a jar of nitrogen, may be relighted in a jar of oxygen, but this must be done so quickly that a spark of fire shall remain on the wick of the candle after this is withdrawn from the nitrogen. This experiment may be varied by using three jars, one of nitrogen, another of oxygen, and a third of common air. In the first the candle will be put out, in the second relighted, and in the third it will burn as usual.

(19.) Nitrogen may be prepared from animal fibre in the following manner:—Wash a piece of beef well, and cut it into small pieces; put these into a retort, and pour some diluted nitric acid upon them. Apply the heat of a lamp, and insert the beak of the retort under a receiver. Nitrogen gas will come over and fill the jar. This is one of the best methods of preparing nitrogen.

(20.) One of the most important points in chemical manipulation, is to make *tight junctions.* We would suggest the following as that which we have found best.—Thrust the end of the retort into the gun-barrel, and fill up the space between with potters' clay. Add enough clay to cover entirely the interval between the gun-barrel and the retort, *so that a strip of cloth will lie evenly over the whole junction.* Then prepare some strips of cotton or linen, an inch or two wide and about two feet long, rubbing moist clay over them. When they are well saturated with clay and covered with a thin, smooth stratum, wind one of them around the clay at the junction, and bind down the whole with a cord of several feet in length. One strip of cloth may be sufficient, but it is generally best to use several. *Before winding the cord over the central part of the junction, bind down with cord the two ends.* This will keep the clay from spreading, and cause the subsequent winding to bind it into one compact and firm mass. In some cases, as where watery vapor is to pass through the tube, white lead may be used instead of, or together with potters' clay.

The analysis of water is continually performed in vegetation. All vegetables have this power, and thus are formed, by the hydrogen of the water and elements within the plant, oils, wax, gum, resins, sugar, &c., while the oxygen is given out by the leaves.

(21.) It is not essential that the necks of the retorts should *pass through* the jar, for the combined gases, or the watery vapor produced by their union, being heated, will rise. The experiment may, therefore, be performed by lighting the hydrogen in the open air *after it has blown off the common air from within the retort* (118.) Apply the lamp to the other retort to drive off the oxygen, and bring the jar, *a*, (with the platinum suspended from the cork and reaching a little distance *below* the jar) above the stream of the mixed gases, so that these shall strike on the platinum sponge.

(22.) The pieces of zinc should be about an inch square, if cut out of sheet zinc; if made from block zinc, they should be *granulated.* For this purpose, melt the zinc in a crucible and pour it out slowly into a pail of water. The zinc will congeal in small masses, or fragments, which may be obtained of any size desired, by pouring faster, or slower, into hot or cold water. The acid solution should contain about 10 parts of water to 1 of acid. The hydrogen from the flask should be tested before being saved, with a *small test-jar*, by which it may be determined whether it has ceased to be explosive.

(22.) Pour some strong sulphuric acid on a few pieces of zinc. The action which may at first take place will soon subside. Now add more water, the action will commence again, and thus it may be renewed several times, by adding a little water each time. Any other metal besides zinc, that is easily oxidized, or *that will easily withdraw oxygen from water*, will produce hydrogen. Any other acid which will dissolve oxide of zinc, may be used instead of sulphuric acid.

(23.) On account of the lightness of hydrogen, a bell rung in this gas will hardly be audible. The bell may be suspended on a frame about the height of a jar, and a string attached which shall reach beneath the jar. Cover the bell with the jar, and introduce hydrogen from the gasometer, or from a flask; if the bell be rung, its tone will continue to grow fainter as the jar fills with hydrogen, until it is scarcely audible.

(24.) For the purpose of inhalation, hydrogen may be, in a great degree, purified by passing it through an alkaline solution. (See arrangement for washing gas "chemical apparatus.") Fill an india-rubber bag with the gas, or fill the *transfer jar* (see "chemical apparatus"), and attach to the stop-cock of the jar an india-rubber tube. Hold the jar over the pneumatic cistern, and inhale the gas. As this is withdrawn from the jar the water will rise, and when it is again exhaled the water will sink within the jar. After three or four inhalations, attempt to speak *before breathing the gas from the lungs*. The effect on the voice will be manifest, but will soon disappear. It is unnecessary to breathe a great quantity of the gas.

(25.) Soap-bubbles may be exceedingly improved by the addition of a very small quantity (1-100 part) of a thick gum-arabic solution. The lightness of hydrogen may also be shown, by taking a bell-glass full of this gas and inverting it. With a taper the escaping gas may lighted at some distance above the bell-glass.

(26.) These tones are best made by a *very small flame* from a *brass jet*. Much depends on the form and size of the jet, which should be small.

(27.) We have generally performed this experiment with a large, broken tube, as the neck of a retort. The same arrangement may be used to perform another experiment. While the hydrogen is burning at the mouth of the bell-glass, introduce a small jet of oxygen from a bladder provided with a stop-cock and gas-jet. This jet of oxygen will burn on the exterior in contact with hydrogen, and, therefore, present a luminous cone, like the common blow-pipe flame (182.)

(Art. 118.) Soap-bubbles blown with the mixed gases explode violently on the application of a flame. A basin blown full of these bubbles will explode with a terrible report. A bladder filled with the mixed gases may be exploded by piercing it with a pointed wire heated red hot. A deafening explosion will ensue. This mixture may be exploded by the electrical spark, and the bladder may, therefore, be prepared with an *interrupted circuit* (as a broken wire, the parts separated about 1-8 of an inch), by means of which, the mixed gases within may be exploded.

(28.) To experiment 22d, this fact may be added, that no *concentrated* acid will act upon zinc and similar metals; a few drops of water will, however, bring on a violent action.

(29.) Cold water takes up 1-750 of lime; hot water only 1-280. A pint of boiling water will dissolve 6 3-4 grains of lime, a pint of freezing water, 13 1-4 grains. Pour a little lime into cold water, and stir it up with the water for a short time, then allow it to settle, and pour off the clear liquid which contains lime in solution. Heat this solution to the boiling point; as it becomes hot it will deposit a portion of its lime, and this will be dissolved again as it cools.

(30.) The water evaporated by plants is perfectly pure; at least it does not contain 1-10,000,000 of foreign matter absorbed from the roots. Hence all the solid matter drawn up with water from the roots of plants, and all the gases with which that water was charged, are absorbed by the plants, and contribute to their nourishment. From the leaves of plants vast quantities of pure water are evaporated. A sun-flower, 3 feet high, evaporated daily 20 oz. of water, a quantity 17 times greater than that lost by insensible perspiration from an equal surface of the human body. For this reason, vines trained on the walls of a brick house often make the building exceedingly damp, and trees near houses have the same effect.

(31.) Many of the lower orders of animals approach nearly to the fluid state. They appear like a soft, transparent jelly, which, by spontaneous decomposition after death, or by the application of heat, is resolved almost entirely into a watery fluid. Thus a medusa weighing 26 or 30 pounds, will be reduced to only a few grains of solid matter.

(32.) A slip of wood set on fire, and held with a pair of pinchers in a test tube until the volatile portions of the wood have passed off in flame, will illustrate the process of making charcoal.—Strong acids take the oxygen and hydrogen from wood, and therefore leave the carbon, or *carbonize* the wood. Heat increases the action of these acids. If, therefore, writing is made on paper with common sulphuric acid, it will be invisible until heat is applied.

(33.) The ancient Britons placed charred stakes in the bed of the Thames, to prevent the passage of Julius Cæsar and his army. These were found nearly a century since, with their heart-wood still solid and firm, and their forms preserved completely. The writings of the ancients are still found at Herculaneum perfectly black. The basis of their ink was finely divided charcoal.

(34.) Recently ignited charcoal, absorbs 95 times its bulk of hydrochloric acid, 90 do. of ammonia, 65 of sulphurous, 40 of nitrous acid, 9·5 of oxygen, 9·42 of carbonic acid, 9·25 of oxygen, 5 of carburetted hydrogen, 1·75 of hydrogen. When agitated with water containing sulphuretted hydrogen, it absorbs this gas and the water becomes inodorous. Clothes may be restored from any disagreeable odor which they may have acquired, by wrapping up in them, for a few hours, some pieces of animal charcoal. Animal charcoal will absorb even lime, when boiled with lime water. This property is not possessed by lamp-black or vegetable charcoal.

(35.) Boil some brown sugar in water, and add to the boiling solution some powdered animal charcoal; continue the boiling, and the charcoal will absorb the color of the sugar. The same effect takes place when the colored solution is filtered through a bed of charcoal 2 feet in thickness. This charcoal may be conveniently placed in a tube or in the broken neck of a retort. Charcoal of charred blood is most efficacious. Wood charcoal has very little decolorizing power. A solution of sulphate of indigo, filtered through a depth of 2 feet of animal charcoal, will pass out entirely colorless. Common vinegar boiled with charcoal powder is rendered colorless.

(36.) Place a large wafer on a pin, or hold it with a pair of pinchers in the flame of a lamp till it takes fire, then remove it over a sheet of white paper. As it burns, the red oxide of lead (291.) is reduced by the charcoal of the wafer, and little globules of bright metallic lead fall out on the paper. Mix 4 oz. of red lead with 1 oz. of charcoal powder in a crucible, and expose the mixture to a red heat for 1-4 of an hour, then pour out the contents of the crucible and metallic lead will run from beneath the powder.

(37.) See 265, 270, 274, 290, 294, 299, 301, (sulphuret of silver in combination with sulphuret of lead), 309, p. 219, 313. In Montserrat there is a mountain which in one part is covered with deposits of sulphur, derived from the decomposition of sulphur vapors which issue continually from fissures in the mountain, attended with great heat. Near these fissures respiration is impossible, and the metallic buttons of visitors are instantly tarnished. The sulphur mines of Sicily, the craters of volcanoes, and the *Solfatera* near Naples, are the chief sources of the sulphur of commerce. At Solfatera, the deposit of sulphur occurs in a kind of sunken plain, surrounded by rocks, which is probably the crater of an ancient volcano. From this since the age of Pliny (A. D. 60.), a considerable portion of the sulphur used in Europe has been obtained.

(38.) The hot springs of Iceland deposit sulphur, and it is deposited by the sulphur springs of New York, Virginia, &c. From the mountain in Montserrat, mentioned above, there flows a rivulet, whose waters boil with violence and are charged with sulphur. New fissures are continually formed in this mountain, while the old ones are stopped up. About two miles distant, there is another similar mountain, with which this is said to have a subterranean communication.

(39.) The sublimation of sulphur may be performed, by placing a small quantity on a hot brick or a hot piece of metal, and covering it with a large bell-glass. A broken bell-glass, or a large broken Leyden jar, if it is to be obtained, should be used, as it is somewhat difficult to remove the coating of sulphur from the interior.—Place a large tube, or the broken neck of a retort, in a sand bath, and inclose a small portion of sulphur on a heated metal or brick within. Heap the sand around the bottom of the tube, to prevent the escape of sulphur fumes. The sulphur will sublime and cover the interior of the tube. One of the best methods is to heat a little sulphur in a Florence flask. The sulphur crystalizes in beautiful yellow stars in the upper part of the flask. In a minute state of division sulphur may be shown by precipitating it from any of its solutions, as from the sulphate of potash or sulphate of soda by baryta water, or from sulphuretted hydrogen by the peroxide of iron.—*Fulminating powder*—nitre 3, sulphur 1, dry carbonate of potash 2. If a few grains of this powder be placed upon a fire shovel over the fire, so that the powder shall heat very gradually, it will at first turn black, then fuse and emit a faint blue flame, and finally explode with a tremendous report. Sometimes the violence of the explosion is so great, that the shovel is indented.

(40) The combustion of phosphorus may be well exhibited by burning a large piece on a tile or a piece of metal. If placed on woolen, lint, feathers, dry paper, or other bad conductors of heat, phosphorus will often pass from a state of slow to that of rapid combustion (104.) It inflames more readily when dusted over with a small quantity of powdered charcoal, or the flowers of sulphur. This spontaneous combustion of phosphorus, or even its oxidation, may be entirely prevented by the presence of a small quantity of olefiant gas, or ether vapor, or that of some essential oil. It may even be distilled in an atmosphere containing the vapor of turpentine in considerable quantity. Even in *pure* oxygen this slow oxidation does not go on, at least at a temperature of 60° ; but if this gas be rarified, or diluted with nitrogen, hydrogen, or carbonic acid, oxidation commences. To show this, place a piece of phosphorus in a phial of oxygen and close the phial. After some hours, open the phial and no fumes will arise. Now mix with the oxygen in the phial, a small quantity of either nitrogen, hydrogen, or carbonic acid, and set aside as before. On removing the stopper of the phial, phosphorescent fumes will be emitted. Place a bit of phosphorus between *two* pieces of brown paper on a table, and pressing on one end of the paper, hold it firmly. Rub a cork over the phosphorus. When sufficiently rubbed, separate the papers, and the phosphorus will take fire and burn rapidly. This experiment illustrates the use of phosphorus in matches, where by sudden *condensation* and friction so much heat is evolved that the matches take fire. To inflame phosphorus under water, put a few grains into a glass tumbler, and pour boiling water over it till the glass is half filled. Through a bent tube project a small stream of oxygen upon the phosphorus, and it will take fire under the water. The tube, in this case, should be of considerable length, as the phosphorus is frequently thrown out of the water by the violence of the action. The extremity should be drawn out to a point, to give a fine stream of oxygen. Phosphorus absorbs oxygen from the chlorate of potash (209.) with explosive energy. One of the most violent fulminating powders is composed of chlorate of potash 1 grain, phosphorus 1-2 grain. If a small portion of this mixture be struck on an anvil, a loud report will ensue. Iodate of potash (210.) may be used instead of the chlorate in the following proportions :—Iodate of potash 6 grs., phosphorus 3 grs. Nitrate of bismuth may be used in the proportions, nitrate of bismuth 4 grains, phosphorus 2 grains. This powder may be exploded by trituration in a mortar. With 2 grs., of phosphorus, either of the following substances forms a fulminating powder;—nitrate of silver 6 grs., nitrate of copper 12 grs., nitrate of mercury 4 grs., nitrate of potash 10 grs. In these cases, the mixture should be wrapped in a paper, and struck with a hammer which has been heated in the fire. If a piece of phosphorus be *pressed* heavily on a small globule of potassium, a vivid combustion will ensue. In this case, *both* the phosphorus and the potassium burn by means of the oxygen of the air, the phosphorus being converted into phosphoric acid (159.) and the potassium into potash (204.) The phosphoric acid thus produced, unites with the base potash to form phosphate of potash.

Sodium may be used instead of potassium in this experiment, and the phosphate of soda will be produced. Chalk, which is carbonate of lime, may be decomposed by phosphorus, which takes the oxygen of the carbonic acid (160.) and leaves behind the carbon and the lime. For this purpose, the phosphorus is placed in a crucible, which is then filled up with chalk, so as to cover the phosphorus closely. The crucible is then covered with another crucible and subjected to a red heat in the fire. It is then removed from the fire, and, when cold, it will be found that the phosphorus has burnt with the oxygen derived from the carbonate of lime by which it was surrounded, and that this has become decomposed into carbon and lime. Phosphorus withdraws the oxygen from nitrate of silver, and the metallic silver thus reduced, covers the phosphorus with a bright film. Phosphorus may be dissolved in ether by boiling in a phial, or small flask, a grain of phosphorus in an ounce of ether. When a piece of cloth is wet with this solution, and then exposed to the air, the ether evaporates, and a thin coating of phosphorus is left on the cloth. If the cloth is now immersed in a solution of gold, the phosphorus withdraws the oxygen from the solution, and the gold thus reduced will cover the cloth in every part.

(41.) Insert a stick of phosphorus in a quill, and write on the wall; the letters will be luminous in the dark. In this, or in any other experiment with phosphorus, the phosphorus *should not be handled except under water or with wet hands*. If the phosphorus takes fire, it should be plunged under water or *smothered* (it cannot burn without oxygen) in some other way. A *luminous mixture* is made of lard 2 parts, rosin 1 part; to the lard and rosin, when melted together, add some pieces of phosphorus, excluding the air immediately by covering the mixture, to prevent the combustion of the phosphorus. When the phosphorus is fully dissolved, the heat may be removed from the mixture, and the latter be uncovered. It will continue to shine in the dark for a long time, and the heat evolved by the gradual combustion of the phosphorus, will be so great as to keep the mixture in a melted state. Phosphoric ether prepared in a phial as mentioned above, will phosphoresce whenever the phial is uncorked. Phosphoric oil (with olive oil) and phosphoric turpentine may be prepared in the same manner.

(42.) Phosphorus, therefore, inflames at a temperature less than that of boiling water (212°), nitric acid (248°, (turpentine (316°), sulphuric acid (620°), &c. Its action with these liquids at the boiling heat, is so violent that it cannot be inflamed on any of them with safety, except on water. It is inflamed on water at boiling heat, by placing it on a small, thin, glass capsule, or any body capable of floating on water and forming a support for the phosphorus *which shall conduct heat.*

(43.) Phosphorus crystalizes in dodecahedrons. These crystals may be obtained from a hot saturated solution of phosphorus in naptha when this solution cools, and may be preserved in the naptha.

(44.) This color is best shown in a gallon jar or bottle full of the gas, which may be collected by the displacement of air. This color will be preserved for a long time if the bottle is perfectly dry, and the gas may, therefore, be saved to contrast with iodine, nitrous oxide gas, &c.

(45.) A little moist cotton placed around the gas tube where it enters the mouth of the bottle, will prevent the escape of chlorine by absorbing it, and will thus prevent the disagreeable effects which this gas produces.

(46.) Fill a quart bottle (of thin white glass) half full with chlorine and the remainder with hydrogen. This may be done over water, but in a place *not exposed to the direct rays of the sun or to bright light*. Place the bottle containing the mixture under a cover of wire gauze, and throw upon the gauze a beam of sun-light from a mirror. The hydrogen and chlorine will unite with explosion, and burst the bottle with a loud report. The experiment may fail if the light is not thrown upon the bottle immediately after the mixture is made. It may be found more convenient to set the bottle in a covered box, which is then placed in the direct sunlight. Draw off the cover from the box by a string, and the mixture in the box will instantly explode.

(47.) The chlorine given off from chloride of lime in the upper part of a house, will soon descend and fill all the lower stories. This it does partly by its greater specific gravity than common air, and partly by the principle of diffusion of gases (193.)

(48.) A splendid combustion may be produced by lowering a globule of potassium in an iron spoon into a jar of chlorine. Chloride of potassium is produced. Chloride of sodium (or common salt) may be formed in the same way. A piece of thin paper wet with turpentine and folded in the form of a match, will take fire instantly on being lowered into a jar of chlorine, and burn with a lurid flame and a very black smoke, arising from the dense deposit of carbon. The paper match should be held with a pair of pinchers, and the excess of turpentine allowed to drop off before introducing it into the jar. Camphor, caoutchouc, ether, &c., continue to burn when inflamed and put into chlorine gas. A jet of chlorine will burn like a jet of oxygen in hydrogen gas (Expt. 27.) (See latter part of Expt. 68.)

(49.) Chlorine in water (chlorine water) decomposes the water when placed in the sunshine, uniting with its hydrogen and giving off the oxygen. For this reason, dilute chlorine water promotes the germination of seeds, as oxygen is the chief agent in producing and stimulating the germination of plants.

(50.) A nosegay of flowers, made damp by previously immersing them in water and shaking off the excess of water, will rapidly absorb chlorine and become bleached. If introduced in a dry state, they will be but little acted on by the chlorine. Pass a stream of chlorine from a small tube into a solution of litmus, indigo, or other vegetable infusion, and in a few minutes the color will be discharged. Pour one of these solutions through a funnel into a flask of chlorine gas. The color will be discharged as before. Litmus or indigo paper is bleached by chlorine. A simple bleaching solution is made by pouring a few grains of the chlorate of potash into a tea-spoonful of hydrochloric acid. This is diluted with water, and substances soaked in it for a short time are bleached. Common writing is effaced when the paper or the writing is moistened and held in chlorine.

(51.) It is soluble in 7000 parts of water, but even this small quantity colors the water brown. Iodine vapor may be shown by volatilizing a small portion in a large jar, similar to that employed for exhibiting the color of chlorine (Expt. 44.) The two jars, placed side by side, will form a fine contrast. The vapor may also be shown, by boiling a little iodine with a few ounces of water in a Florence flask. The vapor of the iodine rises along with the vapor of the water. Iodine vapor is seen to great advantage when a scruple or two of iodine are thrown on a hot plate or brick.

(52.) A lighted taper introduced into the jar of iodine vapor (Expt. 51.) shows a retarded combustion, but a piece of phosphorus introduced on the deflagrating spoon takes fire and burns. Iodine thrown on phosphorus in thin slices, will combine with the phosphorus. Heat will be extricated, and, if the bodies are in contact with air or oxygen, the phosphorus will be inflamed. Three or four thin slices of phosphorus should be employed, and be previously dried with bibalous paper.

(53.) A large vase of cabbage liquor is turned red by a drop or two of sulphuric acid. (Stir the acid in the solution with a glass rod.) Add a small quatnity of alkali, as potash or ammonia, the original colors will be restored, and by adding more, a deep green will be produced. By a second addition of acid the solution can be again reddened, and thus the change of colors produced a great number of times. One grain of oxalic acid (341.) dissolved in three gallons of water, will redden litmus paper. Sulphuric acid diluted 35,000 times with water is detected in the same way. Among the vegetable blues which (*all*) give the acid and alkaline reaction, the following may be selected as examples; —blue morning glory, blue lily, trichostema dichotoma (blue curls), betunia, dahlia, lady slipper, rose (red), miranda. Infusions may be prepared of these flowers as directed for preparing cabbage liquor (see "chemical processes.") The noonsleep produces a fine red color with acids, but no alkaline reaction. The acid we employed in the foregoing experiments was oxalic acid, and the alkali a solution of carbonate of soda. Infusions of green leaves and stems of plants will usually show an *alteration* of color by acids and alkalies. The stain which acids give to cloth, may be removed by adding ammonia, if the latter be applied before the fibre of the cloth is destroyed. If the ammonia is added in excess no harm will be done, as this excess will soon evaporate, and leave the color of the cloth unaltered.

(54.) Make a solution of nitrate of copper so weak as to be colorless. Add a little ammonia to this solution, and an intense blue color will be produced. This color will be neutralized or destroyed by the addition of a little sulphuric acid. It may be again restored by the addition of more ammonia, and thus the color may be produced and destroyed a great number of times.

(55.) Exp. 16 may be repeated to illustrate the formation of acids and alkalies.

(56.) To caustic potash solution 1 oz. add sulphuric acid 1-2 oz. The compound formed by these two corrosive substances, (sulphate of potash) is a mild salt possessing none of the properties of its components —To caustic soda 1 oz. add muriatic acid 1 oz. These corrosive substances form by their union common salt.—Alum is an example of an acid combined with two bases, and is therefore called a *double salt* (253.) Tartar emetic (343) is another example. The acid (tartaric) is combined with the two bases, antimony and potash. The nature of these salts may be illustrated as follows. Add ammonia to oxalate of copper, a *simple* salt oxalate of ammonia is formed, and the copper is precipitated. Instead of pure ammonia, add oxalate of ammonia to the oxalate of copper, and a *double* salt of oxalate of ammonia and copper is obtained. In the first case, where the ammonia was added to the oxalate of copper, the oxalic acid was deficient for both bases—the copper and the ammonia, and, therefore, it *left* the copper for the ammonia. But in the second case, where the oxalate of ammonia was added to the oxalate of copper, the acid was in the right quantity for both bases, and therefore the double oxalate of copper and ammonia was formed.—The double salts are not mere *mixtures* of the simple salts for the crystalization of the double salts is, in many instances, different from that of the simple salts. The double salt may be a rhomboidal blue crystal, while one of the simple salts is a flat, prismatic, white crystal, and the other a green powder, &c.

(57.) Suspend a rose, or a similar flower in a jar of sulphurous acid gas, and it will be bleached. The color, however, will gradually return on exposure to the air, and it may be restored at once by plunging the rose in water.—The fumes of burning sulphur quickly blacken silver, forming a sulphuret of silver. When a thick crust of this sulphuret is thus produced, it may be struck off from the silver by a heavy blow on an anvil, and the silver is left quite clean. By exposing to heat the sulphuret of silver thus obtained, the sulphur is driven off and the silver revived. This, therefore, is one of the methods by which silver coin are sometimes robbed of a portion of their silver.

(58.) The deadly character of sulphurous acid is seen in the common practice of destroying bees by the fumes of sulphur. A bundle of matches lighted, will effectually destroy all the bees of a hive, sometimes 20,000 in number.—Insects for cabinets, are generally destroyed by the fumes of sulphur. The fumes of prussic acid (387.) are to be preferred, as sulphur sometimes injures the colors.

(59.) See Expt. 7. Sulphuric acid expels oxygen from the chlorate of potash (209.), and in this way may be made to set fire to a small quantity of alcohol.

(60.) Dip a piece of sponge into water, and afterwards wring it out, and suspend it while still damp in the upper part of a bottle which holds a little strong sulphuric acid. The acid will attract the moisture from the sponge so rapidly, that it will soon become dry, while the acid will be increased in bulk, in proportion to the quantity of water at first adhering to the sponge.—Into a saucer pour 3 oz. of sulphuric acid, and leave it exposed to a damp atmosphere for 24 hours. At the end of that time, the 3 oz. will have increased to nearly 4, on account of the moisture absorbed from the atmosphere

(61.) A large jar of nitrous acid gas may be exhibited by putting a few grains of copper, silver, or tin, in the bottom of the jar, and pouring a little dilute nitric acid upon the metal. When the jar is full of nitrous gas, put a little wet tow, wool, or cotton over the mouth, and this will absorb the excess of gas, and prevent its escape into the room. The gas thus prepared will form a fine contrast with the bottle of chlorine (Expt. 44.) and that of iodine (Expt. 51.)

(62.) Quills are sometimes dyed yellow. Dip a quill into nitric acid, and let it remain from a second to five minutes according to the strength of the acid. No immediate effect will be perceived upon the quill, but, on taking it out and exposing it to the light, it will turn to a bright and very durable yellow. The quill should be washed in water after being taken out of the acid.—Woolen goods may be colored or marked in the same way. Any desirable pattern may be printed on a piece of flannel or colored cloth with dilute nitric acid, and a permanent yellow color will be imparted to the cloth. After a short time, the superfluous nitric acid should be washed away to prevent its corroding the cloth.

(63) If a piece of glowing charcoal be dropped upon the surface of strong nitric acid, the charcoal will burst into an intense flame. Caution is required in this experiment lest the violence of the action scatter the nitric acid about. If phosphorus is thrown into strong and hot nitric acid, it burns with a splendid combustion. Very small quantities of phosphorus should be used, as the action is exceedingly violent, and the phosphorus is often thrown about in jets of fire. A tall and narrow vessel is generally employed.—From a test tube tied to a long stick, pour a few drops of concentrated nitric acid on bismuth. A rapid combustion will take place, and nitrate of bismuth be formed. Tin, zinc, or red hot iron filings may be inflamed in like manner.

(64.) Carbonic acid may be poured from one vessel to another; it will extinguish a light, or redden litmus solution in the second vessel. A light may also be extinguished by a stream of carbonic acid poured directly upon it.

(65.) Put a few grains of chalk in a tall glass jar, and pour upon it a teaspoonful of hydrochloric acid, carbonic acid will be liberated, and will fill the jar. A lighted taper immersed in the jar is extinguished. An animal, as a mouse, is soon suffocated in the gas.—This gas exerts even a poisonous influence on life. A land tortoise was deprived of one lung by tying up its air tube, and yet supported life by the other for several days; but when one lung was made to breathe carbonic acid, while the other breathed pure air, the animal died in a few hours. An atmosphere containing one per cent. of carbonic acid is injurious, and requires immediate ventilation. Miners however, gradually accustom themselves to an atmosphere containing an amount of carbonic acid that would destroy a person suddenly entering into it without such preparation. But even with miners, frequent accidents occur, showing that habit does not secure them from the deadly influence of this gas.—Insects may be destroyed by immersion in carbonic acid, and be preserved in a good condition for a cabinet.—Carbonic acid also exerts a *positive* influence in checking combustion. The flame of a candle is extinguished in an atmosphere containing only five or six per cent. of this gas.—Carbonic acid gas has been applied to the extinction of fires in coal mines, with great success. These fires may be extinguished in one or two days by this method, while by the old method of sealing up, flooding, and pumping out, great labor was required, and months, or even years of time expended. It has been proposed also to extinguish the fires in ships in the same way. Several vessels containing chalk or broken marble, are to be distributed through the lowest part of the ship, and near them other vessels containing hydrochloric acid. The latter vessels are to be connected with the former by pipes closed with valves. Strong wires lead from these valves to the deck. As soon as the fire is discovered, all means of communication with the external air must be closed, and the valves opened by means of the wires. The vast amount of carbonic acid produced by the contact of the acid with the carbonate of lime will soon displace the common air, fill the whole ship, and extinguish the combustion.

(66.) A white precipitate of carbonate of lime is produced in lime-water, by blowing into the water through a tube or pipe. The carbonic acid of the breath, unites with the lime, and the compound being insoluble is precipitated. A precipitate of carbonate of baryta may be formed from baryta in the same way. The latter is a more delicate test for carbonic acid, than the former, and will soon detect its presence in the air of the room where it is exposed. If a jar be held for sometime over a charcoal furnace, and the bottom then covered with a glass plate and inverted, baryta or lime water poured in will detect carbonic acid in large quantity, by an immediate and dense white precipitate.—The quantity of carbonic acid exhaled, is greatest from 11 A. M. to 1 P. M.; smallest between 8 P. M., and 3 A. M. It is also greater when the barometer is low. By active exercise it is greatly increased. This difference is enormous in insects. Their respiration when at rest, is as feeble as that of cold blooded animals; but when in active movement they consume more oxygen in proportion to their size, than animals of any other class.—The amount of carbonic acid exhaled depends in a great measure on three circumstances: (1.) The amount of active exercise. (2.) The temperature of the body. (3.) The amount of carbonic acid in the air which is breathed. Thus 300 cub. in. of air respired three minutes, gave only 28 1-2 cub. in. of carbonic acid; while *fresh* air respired during the same time, gave 32 cub. in. The proper aeration of the blood is therefore destroyed whenever persons are confined where there is not sufficient ventilation.—Delicate analysis detects a slight difference between the air of a crowded city, and that near the luxuriant vegetation of the country in respect to carbonic acid. During sleep less carbonic acid is exhaled, probably on account of the cessation of muscular exertion, and on account of the warmth of the body.

(67.) See Expt. 46. A better method for observing the union of these gases is to fill a tube 12 in. long, and 1-2 inch *internal* diameter with the mixed gases. Expose the tube to full light. The combustion of the gases will be seen to commence almost instantly by the cloudy appearance produced within the tube. Now cover up the tube and the action will cease until the tube is a second time exposed. Thus by repeating the experiment, the action of the light upon the gases is beautifully shown, while from the small size of the tube there is no danger in submitting the whole to the direct rays of the sun.

(68.) Wrap a jar or phial with a towel, and fill it with the mixed gases, and quickly let fall within a lighted match. A loud explosion will ensue. The jar will not burst if it has an open mouth, and is tolerably thick. After the explosion pour in a little solution of litmus, and it will be immediately turned red, showing the presence of an acid. Into a similar jar of the mixed gases which have not been exploded, if a little litmus solution be poured, the color will be bleached by the free chlorine. If after explosion the bottle be immediately turned mouth downwards into the pneumatic cistern, or a basin of water, the hydrochloric acid gas with which it is filled will be so rapidly absorbed by the water, that the latter will rush up into the bottle until it is entirely filled with water. The jet of chlorine in hydrogen gas (Expt. 48), soon ceases to burn on account of the formation of hydrochloric acid gas within the jar or tube in which the jet is burned.

(69.) Provisions put up by a certain English house were for a long time in great demand for ships trading to the Indies. They were made to keep in a much better state of preservation during long voyages by the addition of a little muriatic acid in each cask. A large fortune was realized by the possession of this secret.

(70.) It may be used to remove blots from books and paper, as it removes the stains of common ink, but does not affect printer's ink. It is generally best to add 1 oz. of red lead to 3 oz. of muriatic acid when used for this purpose.

(71.) See art. 307.—Hydrochloric acid facilitates the germination of seeds which are immersed in it for some days. Seeds which do not otherwise germinate in our climate or in hot houses may be made to germinate in this way.

(72.) Although this gas is heavier than common air, yet bubbles blown with a mixture of sulphuretted hydrogen 2-5, and oxygen 3-5, will ascend. If lighted with a candle, these bubbles will explode with a loud report, forming water and sulphurous acid. Bubbles may also be formed with a mixture of sulphuretted hydrogen 3-5, and nitric oxide 2-5. These bubbles explode and burn with a light green flame. If the gases in these proportions are mixed in a jar and inflamed, a greenish flame will pervade the whole jar.

(73.) Several different colored flames may be exhibited, by preparing bottles with tubes passing through their corks and drawn out above to a point. This is broken off so as to produce a very fine jet of gas. Into one of these bottles place the materials for hydrogen gas, into another the same materials with a few drops of turpentine or ether in the solution, into a third the same materials with a little nitric acid, into a fourth the materials for sulphuretted hydrogen, and into a fifth the same materials with a little nitric acid. All these will, when fired, produce flames of different colors.—After all the sulphuretted hydrogen is collected which is desired, the remainder may be lighted as it issues from the tube, and thus the color of the flame be exhibited, and the offensive fumes avoided.—A jet of large size and great beauty may be formed by filling the gas bag with sulphuretted hydrogen and firing the jet as the gas is driven out of the bag by pressure.

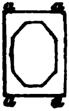
(74.) Images drawn with acetate of lead will remain colorless, until a stream of this gas is made to fall upon the still moist surface. The figures are then brought out of a deep black color (by the formation of sulphuret of lead ;) we have generally formed two figures, one a landscape, the second a *caricature*.

(75.) This gas forms white precipitates with solution of the peroxide of iron, splendid yellow precipitates with cadmium, arsenic, and tin, splendid orange precipitates with antimony, brown with tin, black with lead, copper, bismuth, silver ,gold, platinum, and mercury.

(76.) The discoloration of silver spoons used with eggs is owing to the sulphuretted hydrogen contained in the eggs.

(77.) The vessel of lead should be about 6 inches long, 5 inches wide, and 1 inch deep. The pieces of glass should be cut considerably smaller, and fitted to a wooden support, which is cut out in the centre (Fig. 111.), so that the glass rests upon it only on the corners, *a, a, a, a*. The wooden support should be somewhat larger than the leaden box, and should rest upon this box at the corners. It may be cut in a few minutes out of the wood of a segar box. If the leaden vessel cannot be conveniently obtained, after the plate of glass is covered with wax and the figure drawn, surround it (the plate) with a *raised edge* of wax, and pour upon it dilute hydrofluoric acid. The fumes of the acid should be carefully avoided. The effect may also be produced by dusting the glass with some finely powdered fluor-spar, and adding a little sulphuric acid to disengage the gas from the fluor-spar. A part of the gas will fly off, and may be detected by placing a second piece of glass over the first, but another portion will be retained in the liquid, and this portion will corrode the glass beneath. The latter process will suggest a mode of making a substitute for the leaden vessel, by a plate of glass *entirely* covered with wax, and provided with a raised edge of the same substance.—A thermometer tube, or a similar object, is marked by being coated with wax through which the required lines are traced. The whole is then dipped into sulphuric acid and afterwards dusted with fluor-spar in fine powder.

Fig. 111.



(78.) Silica also serves a very important purpose in the manufacture of *mortar*. It gives strength to the mortar by interposing a hard substance between the loose crystaline structure of the carbonate of lime. It also serves as nuclei for crystalization (like sticks in a saline solution.) Therefore the harder and sharper the sand is, the better is it suited for mortar.

(79.) Silica is deposited in different parts of plants, especially in the footstalks of the leaves. Hence in time the cells and vessels of the plants become clogged with siliceous particles, and this is one cause why the trees of all countries shed their leaves at a certain age.

(80.) Coiled wire and watch-spring, zinc filings and red hot charcoal, will burn in nitrous oxide. A match made of thin tissue paper, which has been dipped in a solution of nitrate of ammonia, will relight in the gas much more readily than a common lamp-lighter. By the combustion of this match, nitrous oxide is evolved in intimate contact with the vegetable fibre, and therefore the match will often of itself burst into a flame, when lighted with a coal of fire. Phosphorus explodes when a small piece (size of a pin head) in a platinum spoon is immersed in nitrous oxide, and touched with a thick iron wire heated to whiteness.

(81.) Dip a long slip of wood in melted sulphur, so that about one half may be covered. Light it, and, while feebly burning, introduce it into a jar of nitrous oxide gas. The flame will be instantly extinguished. Withdraw the match, inflame it again, and when the flame is vivid immerse it a second time. The flame will now be maintained with great splendor, of a delicate red color.

(82.) This mixture may be exploded in a wide mouthed phial, covered with a towel, or in bubbles blown from a gas bag. The explosion is accompanied with a loud report. A bubble of phosphuretted hydrogen (186.) passed into a jar of nitrous oxide gas, will explode with a bright flame. Sometimes these bubbles do not explode at once. In this case, they should not be allowed to accumulate. Tremendous explosions have occurred by inattention in this respect.

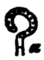
(83.) Paste a slip of litmus paper within a glass jar near the bottom, and fill the jar with nitric oxide. This will not change the color of the litmus paper. Now pass up atmospheric air, and the litmus paper will be immediately reddened. The same experiment may be performed in a more striking manner, by causing the jar to stand in a solution of litmus, or in cabbage liquor, previously made green by an alkali. Oxygen gas produces a more striking effect than common air, and if both the oxygen and the nitrous oxide are pure, the mixture (hyponitrous acid) will be entirely absorbed by the cabbage solution, and this will rise and fill the jar.

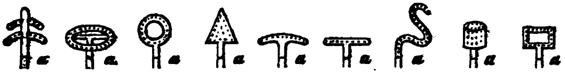
(84.) A mixture of this gas with sulphuret of carbon burns with a blue flame.

(85.) By passing this gas through lime-water (p. 172.), it may be freed from the carbonic acid which it often contains. It will then not affect litmus paper or litmus solution.

(86.) A gas jet for burning this gas, may be made by bending a lead tube, as shown in Fig. 112. The holes in this jet should be as large as a pin's head. This gas will not burn as readily as the illuminating gases, and therefore requires much larger orifices in the jet. Some simple forms of gas jets which may be used for this gas, or for the illuminating gases, *according to the size of the orifices*, are represented in the accompanying figures. These may be made of tin, tipped with a small piece of lead tube, *a*, by which they may be *screwed* on to the transfer jar, or to the stopcock of the gasometer. A red hot iron may be used to inflame carbonic oxide and hydrogen gases, but it will not kindle the illuminating gases (p. 122.)

Fig. 112.



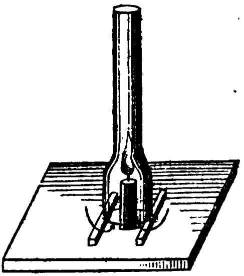


(87.) That even phosphorus is not inflamed unless oxygen be present, may be shown by placing a piece of considerable size in a test tube. The phosphorus will at first take fire, but will be almost immediately *smothered* in its own fumes. It may now be heated quite hot, without further combustion, and appears like a quiet liquid beneath a stratum of white fumes. Into this hot and melted phosphorus, dip a stick which is somewhat longer than the test-tube, and suddenly draw it out to the air. A portion of phosphorus will adhere to the stick, and will burn on coming in contact with the air, with a vivid, and almost dazzling flash.

(88.) This experiment may be exhibited on a small scale by heating the nitre, charcoal, and sulphur, in three watch crystals, or in three metallic disks of similar form. To show the experiment on a larger scale, take a large test-tube, supported by an iron wire around the rim, and into this tube put the nitre and heat it quite hot, then pour in some dry charcoal powder. Another method is to heat in a crucible 1-2 oz. of nitre to a red heat, and then add 1-4 oz. of powdered charcoal. A most beautiful combustion will take place, with almost explosive energy. This experiment appears to the best advantage when the nitre is melted in a Florence flask. When the powdered charcoal is added, a most splendid combustion in the form of a volcano takes place. As the flask is usually melted by the intensity of the combustion, it is necessary to perform the experiment over the pneumatic cistern or a basin of water.

Place the glass cylinder of a lamp over a lighted candle. The candle will soon be extinguished, because no fresh air can enter from beneath. The candle is also extinguished when the cylinder is covered at the top, although the cylinder is so held that the air can gain admittance from below. In this case the candle is extinguished by the burnt gases which surround its flame and exclude the oxygen of the air. But if the cylinder is placed uncovered, on two pieces of wood, the candle continues to burn quietly, and by holding a taper recently extinguished near the lower opening, it will be obvious, from the direction of the smoke, that air rushes in at the bottom but escapes at the top, and thus a constant supply of oxygen is afforded to the flame. If the upper part of a cylinder of a lamp be divided into two channels by a partition down the the middle (Fig. 114.), the candle will then burn, even if access of air be cut off from below. The

Fig. 113.



smoke of a glimmering taper will be drawn inwards on one side, and expelled from the other, as indicated by the arrows in the figure. In common lamps, air has access only to the outside of the flame; hence combustion goes on only at the circumference, and the interior of the flame is therefore dark. But if air be admitted into this interior portion, the dark part disappears. The carbon of the flame is in this way ignited on both surfaces of the flame, and more intensely by reason of the greater heat. On this principle, the *Argand lamps* [Fig. 115.] are constructed. The air is admitted *within* at *a*, *a*, and without at *b*, *b*, as shown by the arrows, and may be made evident by the smoke of a taper.

Fig. 114.

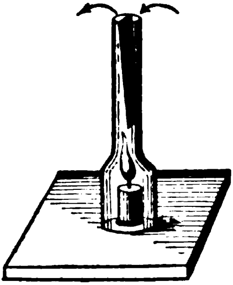
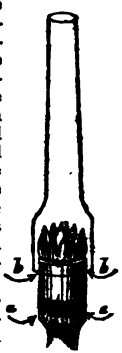


Fig. 115.



(89.) For an inextinguishable match, mix together nitre 4, gunpowder 2, sulphur 1, all in a dry state. Prepare some paper cylinders of thick and hard paper, and place them over nails driven in a board, to support them in an upright position. Now fill them with the mixture, ramming it well. A single nail will in this way hold the paper cylinder firmly to the board. When set on fire these cylinders cannot be extinguished, and will even burn under water.

(90.) Upon a board about 2 feet, long place several heaps of gunpowder about 2 inches apart, wet the powder with turpentine, and connect the heaps with each other by moistening the space between with turpentine. Now apply flame to the moistened heap of powder at one end of the board. The flame will travel over this heap and along the line of gunpowder, without exploding it, to the end, but after the turpentine is nearly consumed, the powder heaps will explode, beginning with the one at the end where the flame commenced, and ending with the most distant pile. The little turpentine that remains in the gunpowder will add greatly to the intensity of its combustion. Alcohol or ether may be used instead of, or in connection with turpentine. Place a piece of phosphorus on some cotton wet with alcohol. Inflame the alcohol, and it will burn without kindling the phosphorus until it has nearly burnt out. Ether or turpentine may be substituted for the alcohol, and sulphur or gunpowder for the phosphorus. Alcohol may be inflamed on a white linen handkerchief without injury to the handkerchief, or on the hand without inconvenience, although *at the point of the flame* glass may be melted. Float a hoop on the water of the pneumatic cistern, and fasten it to the sides of the cistern, so that it will maintain its position on the water. Fill the space within the hoop with alcohol or turpentine, which will float on the water, and set the alcohol on fire. Within the tall column of flame thus produced, the hand may be inserted, by carefully bending the arm through the water below and the alcohol within the hoop.

(91.) The hollow nature of flame may be shown by thrusting one end of a tube slightly inclined within the wick of a burning lamp. A portion of white gas will issue from the other end of the tube, sometimes in sufficient quantity to be inflamed.

(92.) The carbon of gas may be consumed (instead of being ignited) in the following manner, and the result will be a loss of illuminating power. Take a wide tube, or a lamp chimney, and pass through it a current of gas, so that *air from beneath is mixed freely with the current in the tube*. As the current issues from the top of the tube, place over it a wire-gauze, which will have the effect to mix the air and gas more perfectly. If this mixture is now lighted, it will burn with no loss of heat, but with *feeble illuminating power*. The length of the tube being important only to mix the gas and the air, it may be much diminished by placing a wire-gauze about the middle of the tube, in addition to the one at the top.

(93.) The particles of carbon in the previous experiment (92.) being completely consumed, it will be found that no soot will be deposited, this being the unconsumed carbon of the flame.

(94.) A copper wire twisted into a spiral form (Fig. 116.) will so cool the flame of a lamp in to which it is placed as to extinguish it, but if the spiral be previously heated to redness, the flame will not be extinguished. It should be about an inch in diameter, so as to pass over the flame. A jet for the oxy-hydrogen blowpipe (183.) has been constructed on this principle. A tube of brass about 4 inches in diameter is filled with pieces of fine brass wire, which are all tightly wedged together by a pointed rod driven into the center of the bundle. This arrangement presents a great number of metal tubes, very long in proportion to their diameter. The cooling power of this great surface of metal is such as to prevent the possibility of the passage of flame, even that of oxygen and hydrogen.

Fig. 116.

(95.) To illustrate the action of the blowpipe flame, make a *bead* (see "chemical processes") with borax and the oxide of chrome, or the oxides of cobalt, manganese, iron, &c.; also with carbonate of soda and manganese. Show the intense light produced by the flame on lime.

(96.) Bubbles of this gas may be burnt as they rise from the surface of water. The orifices of gas jets (Expt. 86.) for burning this gas should be exceedingly small, not larger than the *wire* of the smallest pins.

(97.) The mixed gases may be exploded in soap bubbles, or as they rise from the surface of water.

(98.) The old temples of the Guebres, or fire worshippers, at Baku, on the western shore of the Caspian sea, are built over jets of inflammable gas, which issue from apertures in the earth. Within an area of two miles in circumference if holes be made in the earth gas immediately rises, and may be set on fire by a lighted torch. Jets of inflammable gas have been observed on a mountain in the island of Samos; also in Bengal in a temple at Chittagong, and in many other places. A current of inflammable gas was discovered in 1828, in the bed of a rivulet on the road between Edinburgh and Glasgow, about seven miles from Glasgow. It was said to be emitted for more than half a mile along the banks of the rivulet. In one place where a large number of jets issued near each other, they were set on fire and burnt uninterruptedly during five weeks, giving the clay soil the appearance of powdered brick.

(98.) Albany, N. Y.,	coal,	Virginia and New Castle,	40 cts.	100 ft. gas.
Baltimore, Md.,	do.	do. and some resin,	40	do.
Boston, Mass.,	do.	Pictou and some Cannel,	35	do.
Buffalo, N. Y.,	do.	Ohio and Pennsylvania,	35	do.
Charleston, S. C.,	do.	Cannel,	60	do.
Cincinatti, O.,	do.	Pittsburg and Youghany,	30	do.
Hartford, Ct.,	do.	Newcastle,	40	do.
Rochester, N. Y.,	do.	American Cannel,	40	do.
Lancaster, Pa.,	resin,		30	do.
Norfolk, Va.,	do.		70	do.

(99.) In front of the retorts in the figure are seen *two* long bars, one of which light colored is the *catch*, the other dark shaded is attached to the lid of the retort. Through the light colored bar or the catch a screw passes, by turning which the lid is pressed closely to the retort. When the retorts are to be opened the screws are unbound, the light colored bar is lifted up from the catch, and swung with the screw attached to it wide open, the lid is then lifted off by the dark colored bar or the handle which is attached to it. Before the lid is again applied to the retort, a mixture of clay and sand is applied around the edge which makes the junction with the retort air tight when the lid is screwed up.

(100.) Ammonia for the purposes of experiment, is more conveniently prepared by distilling liquid ammonia in a Florence flask or a retort. The gas will issue with great rapidity, and may be collected in a perfectly dry flask or tube. When the flask is full, a feather dipped in hydrochloric acid and held near the mouth, will give dense white fumes. The flask may now be corked, but the gas cannot be long retained in this way, as it will escape through the pores of the cork.

(101.) Fill a jar with ammoniacal gas and place in it a piece of fresh charcoal; after 24 hours the whole of the ammonia will be absorbed, no odor remaining.

(102.) Fill a long glass tube with ammoniacal gas, and when quite full, plunge the lower end in a vessel of water, the absorption of the gas will be so rapid and so complete, that the water will rush with force to the top of the tube, and completely fill it.—Fill a bottle with ammoniacal gas, and drop into it a piece of ice; the ice will almost instantly be dissolved, and great cold will be produced by the absorption of latent heat in its liquefaction. If this experiment be performed over mercury, the mercury will rise and fill the jar or bottle.

(103.) Pass a stream of the gas through a solution of litmus previously reddened by a little acid, the color will be changed to a deep blue.—A very dense and beautiful blue color is produced by passing a stream of ammoniacal gas through a solution of sulphate of copper (blue vitriol), so dilute as to be colorless. This consists of the ammoniuret of copper, which is insoluble in water (and, therefore, is at first precipitated), but is dissolved in the water of ammonia, formed by continuing the stream of gas.

(104.) Ammonia may be thus detected in a quill, or in other animal matter, when burnt.—A stream of chlorine passed into a very strong solution of ammonia in a phial decomposes the ammonia, and each bubble in so doing bursts into a flame, with a slight explosion.—If the experiment be reversed, and gaseous ammonia be passed into strong chlorine water, the ammonia will inflame, and continue to burn with a pale lilac flame, producing chloride of ammonium (223) and giving off nitrogen.—Fill two bottles, one with gaseous ammonia and the other with chlorine. Place them neck to neck, the one containing ammonia being uppermost. The gases will mingle with each other notwithstanding the difference of their specific gravities (193.), and their union will generally be attended with flame at the mouth of the bottles.—Pour a solution of ammonia into chlorine water. In this case also chloride of ammonium will be formed and nitrogen given off.

(105.) The ammonia from guano and other rich organic manures may be detected in this way.

(106.) Cut a piece of potassium with a knife; its bright metallic surface will soon tarnish, and become covered with a white crust of potash or oxide of potassium. Place a small piece of potassium on a red hot iron after removing the naptha adhering to it by blotting paper. It will immediately take fire. By its combustion it will form an orange-red powder, which is the peroxide of potassium. If burnt in oxygen it produces the same powder. If to this powder a few drops of water be added, a part of the oxygen is disengaged with effervescence, and potash remains in solution.—Potassium takes fire instantly when placed in chlorine, forming a chloride of potassium.—When thrown on water a part of it combines with the oxygen of the water, forming potash, while the other part unites with the hydrogen to form potassuretted hydrogen. This gas being very inflammable takes fire, and by its combustion is converted into potash and water. Towards the latter part of this experiment the potassium *explodes*, and throws about the potash with which it is covered with considerable force.—The same action will take place if potassium be thrown on ice.—The decomposition of water by potassium may be shown by wrapping a piece of this metal in paper, and introducing it underneath a test-tube full of water, inverted over a basin or the pneumatic cistern. The potassium will rise in the test-tube to the top, and the moment the water reaches it through the paper, part of it will be decomposed, the oxygen combining with the potassium, while an equivalent portion of hydrogen is formed in the tube. The hydrogen may be inflamed by applying a lighted match.—Potassium dropped into sulphuric acid at the bottom of a long tube, will decompose the acid with the evolution of heat and light.—To 2 grs. of iodine in a test-tube 4 or 5 inches long add a grain of potassium, and hold the tube for a second or two in the flame of a spirit lamp. An intense light and energetic action are produced, and the potassium and iodine unite, forming hydriodate of potash. As the tube is generally broken by the violence of the action, the hand should be defended by a glove, and the mouth of the tube turned away from the operator.—Sulphur also combines with potassium with the evolution of heat and light, forming sulphuret of potassium.—A half a grain of sulphur may be used with a grain of potassium.—Take a small globule of potassium and a small piece of *phosphorus* of the size of a split pea. Press the two substances together with the point of a knife on a marble slab, or a warm iron, and they will unite with a vivid combustion, forming phosphate of potash.—Tin and potassium unite when melted together in equal parts in a crucible. Light is evolved at the instant of their union.—In like manner potassium and metallic arsenic unite, forming arseniuret of potassium.

(107.) Place a globule of mercury about the size of a pea, and a globule of potassium about half as large, on a sheet of writing paper. By lifting the paper bring the two metals into contact. The instant this takes place, they will combine with the evolution of heat. The amalgam at first fluid, on account of the heat, will soon become solid, although a small quantity of a solid has been combined with twice the amount of a liquid metal. Put the amalgam into a tea-cup containing warm water. The potassium will here show its greater affinity for oxygen (of the water), than for mercury, by quickly combining with the water, while the mercury is reduced and falls to the bottom. Hydrogen is set free by the decomposition of the water. If the amalgam is wrapped in a piece of muslin and suspended in a tall jar just beneath the surface of the water, the mercury will ooze through the muslin and fall to the bottom, as the amalgam undergoes decomposition. A similar effect will take place, when this amalgam is exposed to the air but less rapidly.

(108.) A piece of dry potash exposed to the air in a very few minutes will become quite damp and soon melt away.

(109.) The following mixture forms a *deflagrating powder;* nitre 4, sulphuret of antimony 2, sulphur 1. These constituents are well mixed on a sheet of paper with a wooden or ivory spatula. A dram, or larger quantity is placed on a piece of dry wood or iron, and fired with a red hot iron. Instant deflagration accompanied by a great heat and dazzling light takes place.—The following mixture is a *fulminating powder;* nitre 10 grs., phosphorus 2 grs. This mixture explodes violently, when struck on an anvil with a hot hammer.—Mix gunpowder with 1·3 its weight of powdered glass. Place a little of this mixture on an anvil, and strike it a heavy blow with a hammer. It will generally explode with a loud report.—Into a crucible containing red hot nitre, throw a few filings of arsenic, antimony, bismuth, zinc, iron, lead, tin, copper, &c. The combustion will be different in the different metals, and sometimes be attended with detonation. The same effect takes place with the metallic sulphurets as with the metals.—Canada balsam greatly augments the explosive energy of gunpowder. The flash of the mixture is as instantaneous as that of gunpowder, and the volume of flame is much greater. A small quantity of gunpowder may be flashed in a wide mouthed phial without exploding it, but if the same amount be mixed with a little thick Canada balsam and put into the phial, and fired by a slow match, the phial will be blown to pieces with a very loud report.

(110.) Pulverize 5 drams of nitre and 5 drams of sal ammoniac, and add 2 oz. of water to them. This mixture will sink the thermometer from +50° to +10° or 40°, and will freeze oil of turpentine, wine water, sea water, milk, and vinegar.

(111.) The experiments given under potassium, may be repeated with sodium.

(112.) *Soluble glass,* (soluble on account of the great proportion of alkali which it contains :) pearlash 10, sand 15, charcoal 4. One part of this glass is dissolved in about 4 of water.—*Plate glass:* white sand 100, carbonate of lime 2, soda 45 to 48, fragments of glass of like quality 100, oxide of manganese 1-4. —*Flint glass:* fine white sand 120, well purified pearlash 40, litharge or red lead 35, nitre 13, and a small quantity of the black oxide of manganese.—*Crown glass:* fine white sand 100, carbonate of lime 12, carbonate of soda calcined 45 to 48, clippings of crown glass 100, and a small quantity of manganese.—*Bottle glass:* common white or yellow sand 100, coarse kelp (carbonate of soda prepared from sea-weed) 30 to 40, lixiviated potash 160 to 170, fresh wood ashes 30 to 40, yellow clay or brick earth 80 to 100, broken glass 100.

Art. 214. Dissolve 3 parts of Glauber's salts in 2 of boiling water, and pour the solution while hot into a phial, and cork the phial tightly. No crystalization will take place, even when the solution is perfectly cold, but if the cork be removed, the crystalization will proceed with rapidity. If this does not take place immediately, the introduction of any solid matter commences it, and the temperature at once rises.

223. *Freezing mixture with sal ammoniac.* Sal ammoniac 5 drams, saltpetre 5 drams, water 2 ounces. This mixture will sink the thermometer from 50° above to 10° below zero. It freezes oil of turpentine, wine water, sea-water, milk, and vinegar.—Dust the hand with powdered sal ammoniac, or place a tea-spoonful of the powdered salt in the hand, and add a table-spoonful of water. The sensation of cold will be very strong.

Page 181. *Colors of porcelain.* Dark purple by manganese, rose color by gold precipitated by tin, orange by antimony, blue in different shades by antimony, green by copper, also by nickel with potash, fine brown by nickel and umber.—*Action of alum on the vegetable colors.* Fill three wine glasses with cabbage liquor, and add to one a little muriatic acid, to the second a solution of alum, and to the third a solution of potash. The liquor in the first glass will assume a beautiful crimson, that of a second a purple, and the third a bright green. An infusion of larkspur and many other flowers will be changed to a *green* by a solution of alum.

Art. 261. Flint glass may be beautifully colored with manganese by pounding it up in a mortar and melting some of the powder thus obtained with a minute quantity of the black oxide of manganese, either before the blowpipe, or in a crucible on the fire.—Mix a minute quantity of manganese with 5 times its weight of borax, and with a brush lay this mixture over an unbaked tile or tobacco pipe. Place the tile in the furnace until it is baked, and the same amethyst color will be produced.

275. Sugar of lead 1-2 oz. dissolve in water. Add ten drops of nitric acid or a little vinegar. In this solution suspend by a string a piece of zinc about the size of a hazel nut, and twist once or twice around the zinc a piece of fine brass or copper wire. The end of this wire should hang down in a tasteful form, as the lead will be precipitated upon it. No part of the wire or the zinc should touch the sides of the bottle. The nitric acid or vinegar is added to the solution to dissolve a white cloudy precipitate, which is often formed when sugar of lead is dissolved in common water, or when it is impure. Filtering the solution, will answer the same purpose.—A tin tree may be formed by dissolving muriate of tin 3 drs. in water, and adding 10 drops of nitric acid. From this solution the tin may be precipitated as the lead in the last experiment.

280. Blue enamels for porcelain are composed of *white enamel* and a minute quantity of cobalt. White enamel is a composition of pure sand 3, chalk 1, calcined borax 3; or broken flint glass 3, calcined borax 1, antimoniate of potash 1. The arseniate of cobalt is the most convenient form in which this substance can be used, as the arsenic acid is partly driven off by the heat, and what remains acts as a flux without producing any color of itself. The addition of a small portion of nitre often brings out a finer color.—The sapphire is imitated by a composition of *white paste* 2 oz., and oxide of cobalt 2 drms. 26 grs. White paste is composed of white sand first washed and purified with hydrochloric acid, and then with water till the whole of the acid is removed. Of white sand thus prepared 100 parts are taken to form white paste, with red lead 150, calcined potash 30 to 35, calcined borax 10, oxide of arsenic 1. These materials are kept in a state of fusion for three or four days. The paste thus formed is that from which all the artificial gems are formed by coloring with various metallic oxides.

281. A landscape may be drawn with India ink, and the foliage painted with muriate of cobalt. Some flowers may be added with acetate of cobalt, others with muriate of copper. After the picture is dry, when cold only an outline of the landscape will be visible, but when gradually warmed the foliage will gradually be brought out of a green color, the flowers painted with acetate of cobalt blue, and those painted with muriate of copper yellow. These colors will again disappear as the picture grows cold. If, however, once strongly heated they become permanent.—*Letters* may be drawn of these different colors which will be invisible when cold but be brought out by heat.

Page 199. *Fusible alloys of bismuth:* bismuth 8, lead 4, tin 1; bismuth 14, mercury 16, lead 32; bismuth 4, lead 4, tin 1, mercury 1; bismuth 1, lead 2; bismuth 3, lead 6, antimony 3.—Melt 2 drams of nitrate of bismuth, and pour the melted metal into a dram of mercury. Melt also 2 drams of lead and pour it into a dram of mercury. When cold these alloys are solid, but when rubbed together they enter into a state of fusion with each other.—Letters drawn with the nitrate of bismuth when dry are invisible, but are brought out of a white color by immersing the paper in water, and of a black color by exposing them to a stream of sulphuretted hydrogen, or touching them with a feather dipped in a solution of sulphuret of potash.—A fine lemon color, the chromate of bismuth, is formed by adding chromate of potash to nitrate of bismuth.

289. Miners detect copper in an ore by dropping a little nitric acid upon the ore, and after a time dipping a feather into the acid, and wiping it over a polished knife blade. If there be the smallest quantity of copper in the ore this metal will be precipitated on the knife.

Page 205. Yellow letters of the chromate of lead may be formed by writing with a dilute solution of chromate of potash on a sheet of paper prepared with a salt of lead, as the acetate.

Page 212. Sometimes a mixed precipitate of the chloride and the sulphate of silver is obtained. These may be separated by raising the temperature of the solution to the boiling point, by which the sulphate of silver will be redissolved, but the chloride will remain undissolved. The experiment may be tried by dropping into a glass of water a drop of sulphuric acid, and one or two drops of hydrochloric acid. Add a little nitrate of silver and the mixed precipitate of the chloride and the sulphate will be formed.

302. Silver is also reduced from its solutions by hydrogen, and by chloride of ammonium. Silk may be silvered with letters, or flowers, or any other figures, by drawing the figure on the silk with the silver solution, and exposing it to a stream of hydrogen gas.

303. The Daguerreotype plate is brought to a high polish by rubbing it with tripoli and rotten stone, to which a little nitric acid exceedingly dilute has been added to insure a more effectual cleaning of the plate. This plate is next exposed in a box to the vapor which rises from iodine at common temperatures, or without the application of heat. In this box it is allowed to remain until it has acquired a yellow golden tint. It is then placed in a second box containing bromine, the fumes of which rising attack the plate and add to the golden color a violet tint. The plate is now ready to receive the picture. For this purpose it is put into the camera obscura. After remaining in the camera the proper length of time it is removed. The effect has been produced on the plate, but this effect is as yet invisible. To "bring out the picture" the plate is placed in a box containing mercury, and exposed to the fumes of this substance for a time. These fumes are raised by the application of a gentle heat from a spirit lamp beneath the mercury. In a short time the image comes out, and to prevent any further action of light upon the picture, the latter is carefully washed in a solution of hyposulphite of soda. This substance dissolves off all the *sensitive coating* of the plate, that is all the coating which has not been already acted upon by light, and fixed by the processes to which the plate has been exposed. The plate is gilded by dipping it into a mixture of the hyposulphite of soda and the chloride of gold. This acts like a varnish, fastening the picture and giving it a more agreeable yellow tint.

In "Talbotyping" the pictures are made on paper. Writing paper of good quality is washed on one side with a moderately dilute solution of nitrate of silver, and left to dry spontaneously in a dark room. When dry it is dipped into a solution of iodide of potassium and again dried. To hasten this part of the process the papers are now generally dried between pieces of blotting or unsized paper. These operations are performed in a room with but little daylight or by candle light. When required for use these papers are dipped into (or rather *floated on*, so as to prepare only one sensitive surface—so of the processes mentioned above) a solution of nitrate of silver, to which acetic acid and gallic acid have been added (just before using), and once more carefully dried. The paper thus prepared is now intoduced into the camera and receives the picture. It is so sensitive that exposure to diffuse daylight for one second suffices to make an impression upon it, and even the light of the moon produces the same effect although a longer time is required. The images when first taken out of the camera are invisible, but are brought out by once more washing the paper in the mixture of nitrate of silver, acetic and gallic acids, and by warming it before the fire. The picture is then fixed by immersion in a solution of bromide of potassium and by washing in water. This is a *negative* picture, that is all the lights and shades are reversed. In order to obtain a *positive* picture the negative is placed over paper prepared for the purpose with chloride of silver, and both papers are covered and *held together* by a glass plate in a frame. The frame is then inclined in the full light of the sun where it remains for a short time, till the rays passing through the light parts of the negative picture have darkened the paper beneath, and thus produced on that paper a reverse picture, or a positive picture. From one negative picture, therefore, many positive pictures may be obtained, and this is, therefore, one of the advantages of this process over the Daguerreotype.

There are many other methods of forming pictures on paper, which have received the names of "chromatype," or colored pictures, "energiatype," from the extreme sensitiveness to light of the paper prepared by this method, "iodatype," where the picture is formed with starch and iodine, &c. All these processes, however, proceed on the same general plan.

One great advantage of Talbotypes over Daguerreotypes is that the former can be seen in all positions, while the latter being formed on a reflecting surface can be seen only in one position. Talbotypes are now made in great perfection in some parts of the country, and perhaps are destined to supersede, in a great degree, Daguerreotypes.

Page 216. Melt a globule of tin to a white heat, and drop it upon an inclined board, it will break into a multitude of small globules, which burn with a bright light as they roll down the board, and mark their course by lines of white oxide of tin.—Tin may be reduced to a finely divided state by pouring it while melted into a wooden box the inside of which has been rubbed with chalk, and by shaking it in the box till it is cold.—In covering plates of iron with tin, the iron is thoroughly cleaned by rubbing with sand. It is then steeped in water acidulated with sulphuric acid. When taken out and dried the plates are gently heated in an oven being first rubbed over with grease to prevent oxidation. In this state they are immersed in melted tin, which not only adheres to the surface, but in a great measure penetrates the whole plate.—Tin plate may be beautifully crystalized by heating it on or before a clear fire until so hot that a drop of water let fall upon it will boil. A wash is then applied to the surface consisting of equal parts of nitric and hydrochloric acids, after which the plate is rinsed in water to remove the acid adhering to its surface. This will be beautifully crystalized. The appearance of the plate may be greatly varied by making one part hotter than the rest before applying the wash.

Page 219. Antimony may be fused like tin under the blowpipe, and thrown on an inclined board. The small globules into which it divides, burn with a very lively flame, throwing out on all sides brilliant sparks.—Metal supports for iron pins are fastened into porcelain door knobs with a solder of lead 35, antimony 1. This solder melts at a very low temperature. It is poured into the knob in such a manner as to catch in three small holes, the excess being removed by a small tool contrived for the purpose.

Detonating powder, with sulphuret of antimony may be prepared with the following proportions: sulphuret of antimony 6 grs., chlorate of potash 3 grs. Place a little of the mixture on an anvil, and strike it a sudden blow with a hammer. It explodes with a loud report and a vivid flame.—*Deflagrating powder*; sulphuret of antimony 2 oz., nitre 4 oz., sulphur 1 oz. Mix the materials well on a sheet of paper with a wooden or ivory spatula, and lay about a dram or more of the composition on a piece of wood or iron. Fire with a red hot iron. Instant deflagration with dazzling light and great heat will be produced.

Art. 310. Mix a few grains of metallic arsenic with twice its weight of gunpowder and an equal weight of nitre. Grind the mixture well, and set fire to it. The antimony will burn with great splendor, producing a whitish blue flame.

313. *White fire*, nitre 24, sulphur 7, realgar 2, pulverized and mixed intimately.

315. If leaf gold be dropped into two glasses, one containing pure nitric acid, and the other hydrochloric acid, the gold will remain undissolved in both. But if the contents of the two glasses be poured together, the metal will be entirely dissolved and disappear.—Moisten white satin ribbon or silk with a diluted solution of gold, and while moist, expose it to a stream of hydrogen or sulphurous acid gas. These gases will decompose the oxide of gold and deposit the

gold in a uniform coating on the silk. In this way any ornamental figures may be laid upon silk, the gilding of which will be permanent.

317. An ethereal solution of gold for gilding is prepared by agitating with a solution of nitro-muriate of gold about a fourth part of ether. When thoroughly mixed, allow the solution to stand until the ether separates in an upper stratum. This will contain the ethereal gold, and may be carefully poured off into another vessel. A polished steel instrument dipped into this solution, and immediately after into water, becomes coated with reduced gold. An ethereal solution of platinum may be prepared in the same way.

354. For 12 gallons of ink take nutgalls 12 lbs., sulphate of iron 5 lbs., gum senegal 5 lbs., water 12 gallons. The nutgalls are bruised and boiled for three hours in a copper vessel of a depth equal to its diameter. Nine gallons of water are at first used, and the remainder added to replace what is lost by evaporation. The decoction is emptied into a tub, allowed to settle, and the clear liquor drawn off. The lees are then drained. To this decoction of nutgalls the gum dissolved in a little hot water and filtered is added. The sulphate of iron is also separately dissolved, and well mixed with the other ingredients. The color darkens by degrees in the air as the iron becomes peroxided. When ink is used in a pale state the writing is more durable, because its particles are then finer and penetrate the paper more intimately. Mould in ink is owing to the growth of a minute fungus. It may be prevented by the addition of a few bruised cloves or other aromatic perfumes.—Write with a weak solution of sulphate of iron. When dry the writing will be invisible. By wetting a feather with tincture of galls and drawing over the letters they will brought out of a black color.

384. For *red* sealing wax melt together with a very gentle heat shellac 48, Peruvian balsam 1, and add gradually the finest cinnabar which has been thoroughly levigated. Mix the ingredients well together by stirring. Or use the following ingredients: pale shellac 1-4 oz., turpentine 1 dram, cinnabar 1 dram, prepared chalk 3-4 dram.—For black sealing wax mix shellac 2 with ivory black 1, and perfume with a little Peruvian balsam or storax. The great seals applied to certain legal documents in England are made of a mixture of Venice turpentine 15, olive oil 5, wax 8, melted together and colored with red lead.—Chrome yellow, azure blue, mountain green, lamp-black, and bronze powder, are some of the substances used to color sealing wax.

389. When potassium is heated in cyanogen it takes fire and burns in a very beautiful manner.

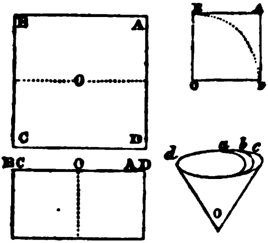
391. Write with a weak solution of sulphate of iron. When dry the letters will be invisible, but a feather dipped in ferrocyanide of potassium will bring them out of a beautiful blue color.—Reddish-brown letters may be formed by using sulphate of copper instead of sulphate of iron.

400. *Colors for Chemists' windows.*—*Green*, verdigris dissolved in water, and acetic acid added;—sulphate of copper 2 oz., salt 4 oz., water 20 oz.; add solution of sulphate of copper to a solution of bichromate of potash;—add nitric acid to a solution of sulphate of copper. *Blue*, liquid ammonia added to a weak solution of sulphate of copper;—Prussian blue 10 grs., oxalic acid 20 grs., water 16 oz. *Lilac*, dissolve zaffre (impure oxide of cobalt) in hydrochloric acid, filter, and add carbonate of ammonia in excess; to this add ammonio-sulphate of copper until the proper color is produced. *Yellow*, quercitron bark, or Indian yellow, or saffron (the last to be preferred), boiled in water. *Orange*, dissolve bichromate of potash until the required tint is produced; sometimes sulphuric or hydrochloric acid is added. *Pink*, rouge dissolved in water;—dissolve zaffre 2 oz. in hydrochloric acid 6 oz., filter, add solution of carbonate of ammonia in excess, then add 1 fluid oz. of potash solution, and dilute with water to produce the required color. *Red*, cochineal or carmine dissolved in water. This like most of the other colors is improved by the addition of ammonia. *Purple*, a little Prussian blue added to the red liquid; sulphate of copper 1 oz., carbonate of ammonia 1 1-2 oz., water 2 1-2 pints. *Violet*, ammonio-sulphate of copper diluted with water, and enough of the pink color mentioned above to produce the required tint. *Straw-color*, gamboge dissolved in water.

Colored inks.—Dissolve in water any of the usual water colors, particularly those which are transparent, and add a little gum water to the solution.

CHEMICAL PROCESSES.

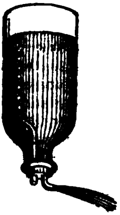
Fig. 117.



Those processes only which are most important, and *which have not been already described*, can be mentioned. Among these are the following :—*Method of making filters.* Fold a piece of thin blotting paper (about 3 inches square) in half, so as to bring the corners C D upon A B, then fold the corner B C upon A D, so as to bring all the corners together at A. These are now all cut off in the dotted line E F, and the filter is finished by separating one of the folds, *d*, from the others, *a*, *b*, and *c*. The filter thus made, may be suspended in a funnel, or in a glass or porcelain hoop.

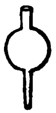
A more convenient method of making filters is to cut a number at once in a circular form. This is done by placing a circular vessel (as a glass jar) over several thicknesses of filter paper on a board, and then cutting around the edge of the vessel with the point of a knife. The paper thus cut out in the form of circles, is afterwards folded as directed above. For common filters, ordinary printers' paper will answer. The filter should generally be moistened with some of the liquid of the substance to be filtered before the whole is poured in. If, for example, the substance is dissolved in water, the filter should be previously moistened with water ; if alcohol is the solvent the filter should be moistened with alcohol. When thus moistened the filter is less apt to be broken by the fluid which is poured in, and it also separates a liquid of a different nature. Thus when water and oil are mixed, if the filter is previously moistened with water the oil is prevented from passing through, and in this way the water and the oil may be separated. *Washing a filter*, or rather the solid substance left on the filter, is done by directing a small stream of water upon it from the washing bottle (Fig. 118.), or the dropping tube (Fig. 119.) The latter is held under water until it is full. The thumb is then placed over the top, and in this way the water is retained in the tube until it is brought over the filter. The thumb is then removed and the water flows out at the lower end of the tube. The dropping tube is of constant use in a course of chemical experiments. *To prepare tubes for corks*, it is often necessary to fuse a narrow rim or edge on the end of the tube. This may be done by the blowpipe, and by pressing the end of the tube while red hot against a smooth block of wood. This fusion strengthens the end of the tube, and prevents its tendency to split apart when a cork is pressed into the tube. *To bend glass tubes*, if the tube is small use the heat of a lamp. Heat the tube on all sides till it begins to fall of itself, then withdraw it from the lamp, and bend it with the hands. A better and more gradual curve can often be obtained by allowing the tube to fall into or take by its own weight while red hot the required form. Large tubes should be bent in a charcoal furnace. *To seal a tube hermetically*, heat it red hot in the alcohol lamp or in a furnace. It may then be *drawn out* to a fine point, and by melting the point thus formed the tube is perfectly sealed. On the ends of tubes which have been sealed hermetically *bulbs* may be blown by the heat of a lamp, but much more readily by the heat of a charcoal furnace, especially if a blast can

Fig. 118.



Price $0.50.

Fig. 119.



$0.25.

be applied to the fire. *To fit a tube within a cork*, a hole the size of the tube is made with brass *cork borers*, or, where these are not to be had, by boring the hole with a red hot iron somewhat smaller than the tube to be inserted, and enlarging the hole thus made with a red hot glass tube. The red hot glass makes a smoother and a more uniform hole through the cork than iron wire, as it retains heat longer, and is itself a smoother surface.

Fig. 120.

Process for making blowpipe beads. The finest platinum wire is selected, and the end bent into a hook (Fig. 120.) This hook should not be *larger* than the extremity of an ever-pointed pencil (so that a pencil lead of ordinary size will pass through. It is moistened and applied to some pulverized borax, and the powder thus taken up is exposed to the blowpipe flame. The water of crystalization is thus driven off, and the borax melts into a transparent bead. Moisten the bead thus formed and apply it to the powder of the substance under examination. Again fuse the bead in the blowpipe flame, and the color which it acquires will in many cases determine the body under examination. An exceedingly small quantity of the substance must be taken on the borax bead, as a larger portion would often render the bead opaque and destroy the reaction. Beads with carbonate of soda and several other substances may be formed in the same manner as that with borax, and are often very useful in detecting the presence of bodies in minute quantities.

In testing with liquid reagents it is generally best to dilute the solution of the substance under examination with distilled water or pure rain water. Hence, take in a test-tube (Fig. 127.) as much of the substance as will fill the convex part of the tube to *a*, add an equal quantity of water, and then drop in the least portion of the reagent which will answer.

Composition and method of using cement. Resin 5 oz., beeswax 1, Spanish brown 1. Melt together and add a teaspoonful of plaster of Paris or brick dust. When melted and well mixed, allow the whole to cool, till it will not burn the hand when this is wet. Then pour into the hands (being wet) a little of the cement, and work it up into a roll or stick. It will be found most convenient in this form. These rolls may sometimes be made on a wet table, and of various sizes. We have found it convenient to have various sizes from an inch thick down to a size even smaller than the ordinary size of sealing wax. *Surfaces to be cemented* should be previously heated, to expel the moisture with which they are almost always more or less coated. On the surface while heated rub a little cement, enough to make a coating. This will insure a perfect adhesion between the surface and the cement when melted and applied in larger quantity. This is the only *sure* way of making perfectly tight cement joints.

In decanting liquids from one vessel to another, it is often not only convenient but essential to prevent any loss of the liquid by running over the side of the full vessel. This may be done by holding a tube or a slip of glass in contact with the lip or edge of this vessel. The liquid will *follow* down the slip or tube of glass into the vessel below without any loss from the above mentioned cause. Short slips and tubes of glass for this and a great variety of purposes, should be kept on hand in a jar or wine glass of clear water, by which they may be always ready for use.

To prepare cabbage liquor, cut up the leaves of red cabbage into strips and upon these pour boiling water, and allow the liquid to stand until cold. When cold pour off the liquor, and it is ready for use. Infusions from other substances sometimes require that the vessel (as a cup) should be placed in boiling water, after this is poured upon the vegetable substance. *Lutes* are made of various substances, such as white lead, plaster of Paris, potters' clay, &c. Where the article to be heated is to be exposed to great heat, the [illegible] lute is made of potters' clay (or even ordi[illegible]) 1 part and white sand 3 parts. In most cases where junctions are to [illegible] are not to be exposed to a jet of steam or to watery vapor, potters' cla[illegible] Expt. 20.) Where watery vapor is to be guarded against, white lead is used.

In boiling certain li[illegible]ullition is often so violent as to endanger the vessel if this is glass. [illegible] ay, in most cases, be removed by dropping into the liquid some particle[illegible]d which will not be acted on, as small pieces of glass, charcoal, brass wire, &c. Small coils of platinum wire are best adapted to this purpose, on account of the insolubility of platinum in most liquids, and its great weight which causes it to remain below the surface of the boiling liquid. *In boiling liquids of this kind the vessel should never be more than three fourths full.*

The liquid to be evaporated must often be protected from dust and other causes of contamination. This is done by covering the evaporating dish with a piece of filter paper of sufficient size. This is supported on three strips of glass which lie across the edges of the evaporating dish in the form of a triangle, and is held down by another strip of glass which is placed above the whole. A better method is to make a *double hoop*, the inner hoop of wood, and the outer considerably wider (an inch and a half) of pasteboard (or also of wood.) The pasteboard hoop slips over the wooden one, and the edges of the filter paper are held between both hoops, so that the paper is stretched across the inner hoop like the head of a drum. A single wide hoop will answer, for a paper cover will last for a long time, and when it is broken through, a second may be pasted over the whole.

Among the *conveniences* of a laboratory, wire of different kinds and sizes should always be at hand. Small copper wire (binding wire) is of constant service. Wire *triangles* of different sizes are often useful, particularly in supporting objects over a furnace or a lamp. A very convenient small portable furnace may be made by inverting the wire cover of a mouse trap. A few pieces of ignited charcoal thrown into this furnace, produce a far higher and more uniform heat than that of an ordinary alcohol lamp. Lamp-lighters made of paper are also frequently very useful. Important experiments may be rendered unsuccessful for want of small facilities of this kind. They may be kept on hand in a jar.

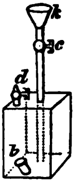
It is frequently desirable to increase for a short time the heat of an alcohol lamp (as in the process of making oxygen gas.) This may be done by holding a strip of newspaper or any other waste paper in the lamp. It will be found very convenient to keep on hand a quantity of paper for this purpose. The heat of a lamp, if this has a broad top, may sometimes be most conveniently increased by adding with a pair of pinchers or tongs small pieces of cotton which have been dipped in alcohol. A great volume of flame may be in this way produced. No danger is incurred if the lamp is a metal one, and the cotton may at any time be removed should the heat become too great.

To save time in *cleansing apparatus*, it may be well to keep on hand a bottle of potash solution, and another to receive strong acid solutions, which, containing various impurities from use, are unfit for any other purpose. Flasks may often be cleansed by agitating wet paper, alone or mixed with wet sand, within them. Test-tubes may be cleansed by a *swab* made to fit them of a stick covered with lamp wick or strips of cotton cloth, or better by *teasel* attached to an iron wire and fitting the test-tube.

CHEMICAL APPARATUS.

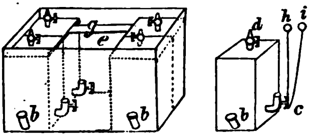
Gasometer. The cheapest form of gasometer is represented in Fig. 121. It consists of a tin or wooden box, to which are attached a funnel tube, *k*, made of tin, and extending nearly to the bottom of the box, a stopcock, *d*, and a short tube, *b*, opening into the box near the bottom. This short tube is stopped with a cork or a metal cap. The gasometer is filled with water by stopping *b*, and opening *d*, and also *e*, which is a stopcock in the funnel tube. Water is then poured in at *k*, by which the air is driven out of the gasometer at *d*, and the gasometer filled with water. When full *c* and *d* are shut and *b* is opened. Little or no water escapes when *b* is opened, as the water within the gasometer is supported by the pressure of the atmosphere.* The gas is collected by thrusting the tube from which it is delivered through *b*, *entirely within* the gasometer. The gas is then heard to bubble over, and rises to the top of the gasometer within, while an equal bulk of water escapes through *b* (around the gas tube which is not so wide as *b*, and therefore occupies but a portion of its cavity.) When the gasometer is full of gas, *b* is closed and a flexible tube attached to *d* ; *c* is then opened, and water poured in at *k*. This descending into the gasometer expels the gas through *d*, and through the flexible tube attached to *d*, by which it is conveyed where it is desired. The contents of the gasometer should be at least a cubic foot.

Fig. 121.



The *pneumatic cistern* is made so as to contain one or more gasometers with other conveniences for collecting or decanting gases. In Fig. 122 is represented a pneumatic cistern with four gasometers. Two are placed on each side with a wide space, *e*, filled with water between. Water also flows over the tops of all the gasometers, these being placed a little below the top of the pneumatic cistern. These gasometers differ from that represented in the last figure only in having a short tube, *c*, on the side, the stopcock of which may be opened or shut by the wires, *h* and *i*. These wires extend nearly to the top of the water, and this arrangement takes the place of the funnel tube, *k*, in the last figure. When the space, *e*, is filled with water, *b*, *b*, *b*, *b*, (the two last belonging to the two *interior* gasometers are not represented) are shut, and the four stopcocks on the gasometers (*d*), as well as the four valves (*c*), are opened. The water then flows in from the space *e*, into all the gasometers through the valves (*c*), while the air is driven out through the stopcocks (*d*). When all the gasometers are full of water, they may be filled with four different gases, or with the same gas, by stopping the valves (*c*) and the stopcocks (*d*), opening *b*, *b*, *b*, *b*, and thrusting the tube conveying the gas through these short tubes entirely within the gasometer as before. When filled with gas this may be expelled from the gasometers by closing *b*, *b*, *b*, *b*, opening the valves (*c*) and the stopcocks (*d*), the space, *e*, being kept full of water. The water now runs in through *c*, and the gas escapes from *d*. Over the space, *e*, is seen at *g* a sliding shelf which slides along on the edge of the gasometers. There is an opening through this shelf, and a short funnel attached beneath by which gas may be conveyed *upwards* to a jar filled with water and standing on the shelf.

Fig. 122.



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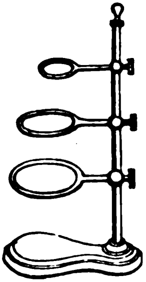
*The same principle is applied in the construction of a common form of inkstand.

The following articles of apparatus have been mentioned in the preceding pages of this work, and are therefore inserted *partly* for the sake of reference.

Fig. 123.

Lamp Stand.



$1.50.

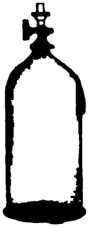
Fig. 124.

Stoppered Jar.

$1.50. 4 qts.

Fig. 125.

Transfer Jar.



$3. 4 qts.

Fig. 126.

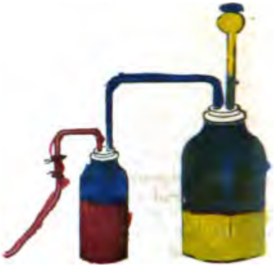
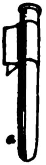


Fig. 126 represents the arrangement for *washing a gas*, as hydrogen (Expt. 24.) The gas is generated in the larger bottle and passed through lime water or some other purifier in the smaller bottle. In Fig. 127 are seen a test tube and holder.

Fig. 127.



The holder is formed by folding up a piece of paper into a strip about an inch wide and four inches long, and containing four or five thicknesses of paper. This strip is wrapped about the tube, and held at the two ends. Test tubes are sold at about 50 cents per dozen, the price depending upon their size and quality.

The extremity of the common blowpipe (Fig. 129.) may be coated with varnished paper to prevent the bad taste of the brass tube in the mouth. It is sometimes gilded by the electrotype process for the same reason. The Berzelius blowpipe (Fig. 130.) has a platinum jet, an ivory mouth-piece, and an ivory *reservoir*. It is made in four pieces with ground joints.

Fig. 128.

Deflagrating Spoon.

$0.25.

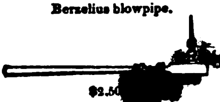
Fig. 129.

Common blowpipe.

$0.38.

Fig. 130.

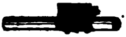
Berzelius blowpipe.



$2.50

Flexible tubes are either of lead or caoutchouc. The latter are to be preferred, but a lead tube, 2 or 3 yards in length and provided with a stopcock on one end, is often very convenient. Three or four *brass stopcocks* should be obtained, and as many screw connectors. The former are sold at $1.00 each, the latter at $0.25. *Sheet India rubber* may be obtained for $0.50 per square foot. Fig. 131 represents the method of making India rubber connectors out of sheet India rubber. A small strip of India rubber is wrapped around a tube of the required size. The ends of the strip are then cut off by a pair of scissors in the direction represented by the dotted line. The new cut edges unite with each other, and their union may be rendered more perfect by pressing them together with the nail (but without touching them.) The India rubber connector thu[illegible]ormed may be slipped off from the tube, and applied to the purpose for which it is be used. Connectors may be had ready made at 75 cts. per dozen, and a few will last a long time and serve a great variety of purposes.

Fig. 131.



A *measuring glass* is often required. These glasses vary in size, form, and mode of graduation. It is therefore best, if possible, to have more than one kind. They vary in price f[illegible] 50 cents (holding one fluid ounce) to $1.50 (holding sixteen ounces).

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Zinc - - - - - - 194

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This book should be returned
the Library on or before the last da
stamped below.

A fine of five cents a day is incurred by retaining it beyond the specified time.

Please return promptly.